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ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS

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OCTOBER, 1972

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ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS

PROCEEDINGS OF THE PUBLIC HEARINGS

OCTOBER, 1972

PART II

ENVIRONMENT CONSERVATION AUTHORITY
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PUBLIC HEARINGS CALGARY

OCTOBER, 1972

ENVIRONMENT CONSERVATION
AUTHORITY
9912 - 107 Street
Edmonton, Alberta
T5K 1G5

Submission to the

ENVIRONMENT CONSERVATION AUTHORITY

respecting

The Environmental Effects of the Operation of Sulphur Extraction Gas Plants in Alberta.

Presented by: W. Chalmers

By: Petrogas Processing Ltd.
Calgary, Alberta.
September, 1972.

SUMMARY

Petrogas Processing Ltd. has been operating a gas plant with sulphur extraction facilities and field gas gathering facilities in the Crossfield field since 1961. Because of the proximity of operations to the City of Calgary, its significant size (design capacity of over 300 MMCF/D and 2000 LTD sulphur), its pioneering history and involvement in sulphur recovery technology plus its comparatively lengthy operating period with resultant associated experience, the following observations can be made.

1. Extensive monitoring coverage involving the use of continuous sulphur dioxide recorders, sulphation cylinders, dustfall containers, ground water analysis, false color infra-red photographic and soil surveys and corrosion coupon stations indicate that in our operating area, the quality of the total environment, air, water and soil, generally has not been reduced or damaged by eleven years of operation.

2. A minor qualification to the above statement should be recognized. In a very local area, adjacent to the original sulphur stockpile, sulphur dust had reduced soil fertility. Compensation is being paid in this regard and restoration of the area is in progress. The sulphur is now stored in a slated form and there is no material local dusting problem.

3. The imposed limit of 0.15 PPM for 15 minutes SO_2 ground level concentration, the most restrictive plant operating limit in the province, is being met 99.7% of the time. In line with the observations of 1. above, this limitation along with the applicable ambient air standards, are providing more than adequate environmental protection.

4. Company field and plant operations are conducted under practical safety and maintenance schedules and good housekeeping practices, and create no "side effects" problems. The plant has recently passed the 1000-days-without-a-lost-time-accident mark. A majority of the supervisory and senior operating personnel have approximately ten years of company employment, an enviable record considering the attrition experienced because of other sulphur operations starting up and requiring experienced personnel during this eleven year period.

5. The company has been a leader in the field of Claus technology. Recovery efficiencies have improved materially over the years and we can expect continued improvement with time. By on going operations oriented research, it has been demonstrated that a Claus recovery unit, with an unfavourable gas, can at this date, challenge the validity of the previously accepted theoretical limits. Therefore,

having regard to existing sulphur prices and the current state of the art, there is no economic or environmental justification for imposing mandatory, supplementary recovery techniques on existing operations where ambient air standards are being met.

6. The operations of Petrogas are in the public interest of the Province of Alberta. The economic and social benefits of this plant to the Municipality in which it resides, to the City of Calgary, the Province and even the nation, as well as to the Company itself, are meaningful. The contributions that Petrogas makes in the areas of employment, gross revenues, services and supplies are net benefits. On the other hand, the Management of Petrogas appreciates the need and has demonstrated an ability to establish a suitable balance between the economic benefits to the community and the ecological impact of the investment.

RECOMMENDATIONS

1. It is our experience that by conscientious operations subject to monitoring control, the quality of the environment can be maintained. It, therefore, is recommended that ambient air quality standards be the regulating factor in sulphur plant operations, rather than an arbitrary sulphur recovery efficiency or point source emission limitation.

2. Present ambient air standards are more than adequate for environmental protection and may be met realistically by plant operations. It therefore is recommended that existing standards not be changed.

3. In the whole of the environmental concern arena, where emotion, politics, and science all play important parts, it is recommended that relations between industry and government should be maintained on this important matter, such that their discussions can lead to an intelligent environmental policy acceptable to our society.

THE ENVIRONMENTAL EFFECTS OF SULPHUR EXTRACTION PLANTS

Submitted By:

PETROGAS PROCESSING LTD.

INTRODUCTION:

The Petrogas complex is located in the Municipal District of Rockyview, approximately twelve miles north east of the Calgary International Airport.

Canadian Occidental Petroleum Ltd. of Calgary is the plant operator and a major shareholder of Petrogas Processing Ltd.; in addition, Canadian Occidental provides the management, technical and financial expertise for the company.

GENERAL:

The plant is situated in approximately the geometric centre of the Crossfield gas field. The gas field encompasses an area in excess of 200 square miles and contains three distinct and separate gas zones. Two of the gas zones, the Elkton and Basal Quartz, are relatively sweet, that is, their H_2S and CO_2 contents are one percent and ten percent, respectively. The third zone is the high H_2S Crossfield gas zone, having an analysis of 27% to 33% H_2S and 5% CO_2.

The discovery well of the Crossfield zone was drilled in 1954; follow up drilling led to the Elkton discovery in 1957. At commencement of operations in 1961, nineteen wells were available for production to the plant facilities, thirteen were producing from the high H_2S Crossfield zone, the remainder were Elkton wells.

As a result of further development drilling and plant expansion, fifty wells are now producing to the plant as required.

PLANT INVESTMENT:

The initial investment in plant and field facilities amounted to $13,000,000. Since start-up in 1961, expansion of the facilities, upgrading to meet technological advances and changing environmental regulations has required additional infusions of capital. Up to 1972, the total capital invested in the Petrogas operation exceeded $42,000,000. An additional $30,000,000 has been expended in well drilling and completion costs.

PLANT CAPACITY:

Five commercial products are available from the plant facilities on a continuous basis; sales gas, condensate, propane, butanes, and elemental sulphur.

The plant is designed to produce up to 215 MMCF of sales gas on a daily basis from a mixed raw gas feed of 325 MMCF/D. The gas is sold in both the export and domestic markets.

Facilities exist to produce up to 4,000 bbls/day of condensate which is transported by pipeline to the local refineries for further processing. The product surplus to local requirements is exported. Since the initial start-up to year-end 1971, 8,468,636 barrels of condensate have been transported from the plant site.

The L.P.G. products, propane and butanes, amount to approximately three-quarters of a million barrels per year. An extensive local heating market is serviced directly from the plant, the remaining product is exported for chemical plant feed-stock.

The Petrogas sulphur recovery facilities were, until quite recently, the largest on the North American continent, having a capacity of 2,000 tons/day. During the ten year period, 1961 to year-end 1971, a total of 3,835,302 long tons of sulphur had been shipped from the plant site.

PERSONNEL:

An average complement of 100 employees is required to staff the plant. Local contractors are employed to supplement the plant staff during peak maintenance periods and for specific projects. The company has a continuing policy of maximising local labour to the extent possible for all positions within the company.

Due to the toxic nature of the gases processed in a high pressure sour gas plant, safety is an integral part of the operation. Recently, the plant staff exceeded a record one million man-hours without a lost time accident.

The plant safety achievements, to year-end 1971, were appropriately recognized by gas processors and the Alberta Workmen's Compensation Board. A continuance of the excellent safety practices will qualify the staff for a superior award.

OPERATIONS HISTORY

The Petrogas complex could be termed a typical gas processing plant inasmuch that it utilizes a diethanolamine scrubbing process to strip the gas, the gas treating units are followed by a single train L.P.G. unit and three Claus sulphur recovery units.

The history of Petrogas is, however, a record of achievement and progress. During the period 1959/60, when the plant facilities were in the design stage, high pressure, sour gas processing was still in its infancy, particularly when considering gases with hydrogen sulphide concentrations between 27% and 33%.

At start-up in 1961, the two original sulphur plants, recovering sulphur from sour gas, were the largest on the North American continent and the second largest in the world.

The early years of operation were extremely difficult; the operating technology was literally developed on a day to day basis. There were no text books or operating manuals that could be used as references.

During the period 1965/66, the plant and field facilities were completely reviewed in preparation for a major expansion. The highlights of the expansion were the construction of an L.P.G. unit, the expansion, conversion and modification of the sulphur plants and gas treating trains.

Some notable firsts for the industry were achieved at this time. The company designed and installed the first insulated/heated sour gas gathering system. The world's largest single train sulphur recovery unit, with a capacity of 1100 tons per day was completed. All sulphur plants were converted to a three stage arrangement and all were designed for 97% recovery efficiency. Two 400 feet high stacks were built permitting the plant to operate with a calculated ground level concentration of 0.15 PPM SO_2, at the full design load of 2000 TPD. An operating approval permit was subsequently issued on this basis.

It is of some importance to recognize these major design features were considerably in advance of their time; they were solely a decision of responsible management and made without external pressures. At that period in time, sulphur plant efficiencies varied between 93% and an exceptional high of 95%; ground level controls in comparable areas had a requirement of 0.20 PPM SO_2.

Excellent results were obtained from all the expanded and modified facilities and all design objectives were met. The heated pipeline was particularly successful and resulted in a total conversion of the complete gathering system. It was also the prelude to the completely closed system which virtually eliminated field flaring. The system design permitted all well effluents to be transported with the gas through the pipeline to a central treating and disposal facility. The totally closed well and gathering system was completed in 1969, and has contributed significantly to the air quality of the area.

During 1968, with the advent of more frequent stack testing, it became evident that a major discrepancy existed between the accepted method of sulphur plant testing and the new stack methods.

It was 1969 before the technology was developed to ascertain the nature of this discrepancy. A complete stage by stage analysis of each plant, by chromatography, revealed that undesirable side reactions were occurring in the furnace. The reactions formed the sulphur compounds carbonyl sulphide (COS) and carbon disulphide (CS_2). By analytical methods, it was determined that the typical sulphur plant catalysts did not have the ability to convert these compounds back to sulphur. As the analytical techniques were improved, it became evident that this was a major problem at Petrogas; forty percent of the atmospheric emissions were originating from this source.

The information gained from the work during 1969 accelerated a progressive on line research program and upgrading of the sulphur plants to meet this new challenge.

A completely new supervisory instrument and combustion control system was developed by the company staff in conjunction with a leading contractor. Catalyst studies progressed, and by late 1970, Petrogas had pioneered the use of hydrotreating catalysts in a Claus plant and were operating at efficiency levels close to the previously accepted theoretical limits.

The Petrogas management is of the opinion that the Claus efficiency can be further improved, with time, even though each of the plants has to date demonstrated an ability to exceed 97% for a sustained period and can be relied on to maintain 97% recovery efficiency, with progressive catalyst changes.

To support this opinion, on line research continues at the operating units by the plant staff. The company also supports research by others in Claus technology and catalyst studies. It is now the general opinion of the people closely involved that most of the remaining problems have been defined.

The results achieved by the management and staff of Petrogas Processing Ltd. has resulted in significant gains being made, both in the basic Claus technology and by a material reduction of SO_2 emissions. The future outlook for the Claus process is therefore one of optimism and is considerably brighter. We may anticipate that in the near future, sulphur recovery plants will be capable of operating continuously, without frequent catalyst changes and with efficiencies up to the present theoretical limits.

THE ENVIRONMENTAL IMPACT OF THE INVESTMENT

Petrogas Processing Ltd., due to its proximity to the City of Calgary, operates under the most stringent SO_2 emission control in the Province. The plant operating permit is based on control of ground level concentration of sulphur dioxide by continuous monitoring of data back to plant control.

The following requirements have to be met:

Maximum ground level concentration for a 15 minute period is limited to .... 0.15 PPM

With seven continuous monitors in service, total atmospheric sulphur emission is limited to ...... 100 TPD

With less than seven continuous monitors in operation, total atmospheric emission is limited to .... 61 TPD

Reference E.R.C.B. Approval 1477A.

To meet these requirements, the plant is controlled and operated with sophisticated equipment and with considerable attention to detail in the day to day performance.

In contrast to the approved emission levels, the actual emissions of atmospheric sulphur since March 1, 1971, the date of start-up of the seven station monitoring scheme, were lower and averaged approximately 58% to 60% of the permitted level. It is of interest to note that in a recent proceeding before the Energy Resources Conservation Board, Petrogas sought authority to operate in the future under approved conditions equivalent to a maximum sulphur emission level of only 51% of the existing emission approval. That the historic and requested emission levels result in no damage to the environment is well documented as summarized by the following statements.

Results to date indicate that the Petrogas method of control has been eminently satisfactory. The on-line time of the monitors, since inception of the system, has been excellent and the incidence of readings exceeding the 0.15 PPM has been extremely low. Data extracted during the period of April, 1971 to March, 1972 indicates the following results.

The provincial standard of 0.30 PPM SO_2 for one hour was exceeded on two occasions, amounting to 0.035 percent of the time.

The ambient air quality standard of 0.1 PPM SO_2 for 24 hours was not exceeding during the period.

The provincial ambient air quality standard has been met better than 99.96 percent of the time. Furthermore, the measured ground level concentration of sulphur dioxide of 0.15 PPM for a 15 minute period (E.R.C.B. Permit) has been met for approximately 99.7 percent of the time.

To equip the plant and field to operate on ground level control, rather than stack emission, required considerable capital investment, and an aggressive management policy.

The total plant monitoring system consists of the following:

Closed loop control of acid gas combustion by chromatographic control with pressure and temperature compensation and a four component chromatographic read-out of H_2S, SO_2, COS, and CS_2 in sulphur plant tail gases, (3 plants);

Continuous stack monitoring with direct instantaneous chart reading of sulphur emission in long tons per day and stack concentrations of SO_2, (2 stacks);

> Seven remote and strategically placed monitoring trailers, each equipped with up to date SO_2 analysers. Two of the trailers are equipped with continuously recording H_2S analysers, four have wind recording instruments. All data is recorded locally at the monitoring trailers and selected data is telemetered to the plant control centre for instant reference. In the event of a high level indication, an alarm will announce the fact and will precipitate plant correctional procedures prior to the peak occurrence.

Supplementing the data retrieved from these more elaborate sources are forty SO_2 and H_2S sulphation sampling stations. The stations, which have been continuously in service since 1961, are dispersed throughout the field to the satisfaction of the authorities. To obtain additional information and background sulphation data, additional stations are maintained out beyond the field perimeter. For comparative and control purposes, the Department of the Environment also maintains a number of sulphation stations.

An analysis of the results from both the Government and company operated stations since 1967 indicates good control with a continuously decreasing trend.

Reference - Figures 1 to 5.

The quality of the environment is, however, somewhat more than just sulphur dioxide ground level concentrations. A number of years ago, the company instigated a general water quality survey in its area of operations. This survey is conducted on an annual basis and involves a complete analysis of waters from sloughs, and lakes, plus domestic and stock wells. Over this period, a history has been developed which reveals that the plant and field operations have not been detrimental to water quality in the area.

It had been noted on occasions that certain water wells were of marginal quality. As a public service, the appropriate authority and the residents were made aware of the situation and the information was greatly appreciated. These incidences were few and resulted from bacteriological and nitrate conditions, both totally unrelated to plant operations.

To combat the problems associated with dusting during sulphur loading, the plant has been converted from sulphur crushing/loading to a sulphur slating operation. Sulphur slating is a relatively dust free operation. Twelve dustfall sampling stations, selected by the Department of the Environment, monitor any dustfall possibilities.

As an additional service, Petrogas has maintained a network of atmospheric corrosion stations since 1968. These stations monitor and simulate the possible environmental effects on residential paints, farm implements, telephone and fence wires. The stations are located, for comparative purposes, both inside and outside the area of operations. The data retrieved to date, indicates that the atmospheric corrosion conditions, which exist in the plant area, are superior to those in some major Canadian cities and surprisingly, in areas of Alberta not associated with sour gas processing.

Reference - Tables 1 to 3.

The development of environmental technology as it relates to measurement and analytical procedures has been extremely rapid over the last few years. The Petrogas management has acted in a responsible manner in this regard by evaluating the various devices and techniques as they became proven and have not been hesitant, or reluctant, to implement any sound new practices. On occasions, the technology has been developed by the staff, to suit certain inadequacies, unique to the Petrogas operation.

A major development of recent years has been the use of false colour infra-red aerial photography to determine areas of vegetation stress. During the summer of 1972, after approximately eleven years of operation, the plant area and adjacent gas fields were extensively covered by aerial photography. All doubtful areas indicated by the photographic survey were traversed, on foot, by specialists.

The opinion submitted by these experts indicated there was no evidence of crop damage which could be attributed to either sulphur dust or sulphur in a gaseous form, with the exception of one small area. This particular area was known to the operator; the damage was directly attributable to the loading of crushed sulphur for export.

Suitable compensation had been previously and promptly arranged with the owner and appropriate action taken to correct the situation. All sulphur loadings for export have been of the flaked variety since May of 1972.

They further stated that alfalfa, a crop most susceptible to acidification of the soil, was flourishing in fields which had good farm management. Conifers, in tree shelter belts, some of which would be susceptible to heavy concentrations of SO_2 were also flourishing.

Reference - Attachment 1.

An excellent relationship with the neighboring residents has developed over the years. This did not result from any sophisticated public relations program, but resulted more from responsible operation.

Any problems that did arise were promptly investigated and it was appreciated that the personalities involved did have a point of view and possibly were concerned.

The only complaints received during 1971 resulted from the use of sterilants for weed control at well-site leases; the sterilant caused minor crop damage adjacent to certain leases. In each case, equitable compensation was promptly arranged with the property owner.

It is of some significance to note that during a recent public hearing to review the Petrogas operation, no intervenors or complainants, from either Government or the public sector appeared. The hearing was held in Calgary and was conducted by the Energy Resources Conservation Board.

A fact of major interest is that the area of operations is being extensively subdivided to twenty-acre residential lots, some in relatively close proximity to the plant site. The development and occupancy rate appears to be quite high. It is not unreasonable to assume that this could be construed as tacit approval of the conduct of operations.

THE ECONOMIC IMPACT OF THE INVESTMENT

The economic impact of having a gas plant in the area is of major significance. Taking Petrogas as an example, located twenty miles from downtown Calgary, it employs directly 100 people, approximately 90% of the personnel live in Calgary, the remainder in close proximity. The wage and salary bill exceeds one million dollars annually.

The plant returns an annual operating budget in the order of $3,500,000. The major portion of this budget will go directly into the economy of Calgary, to the support and supply industries. The following extracts from a typical budget illustrate the magnitude and distribution of funds after wages and salaries, and is presented on an order of magnitude basis.

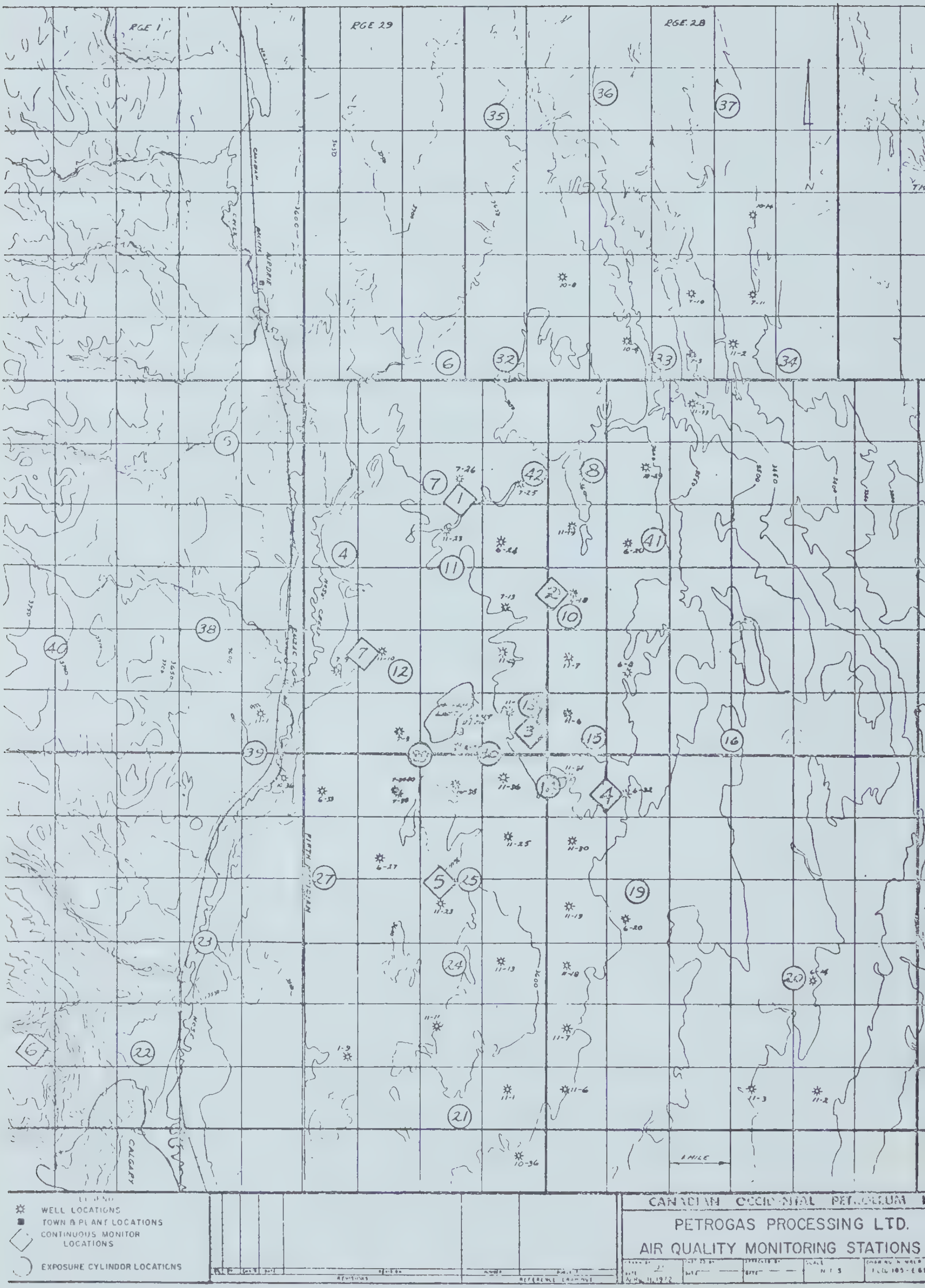
Supplementary labour and services	$300,000
Property Taxes	$240,000
Power	$160,000
Transportation	$300,000+
Communications	$ 12,000
City of Calgary (Utilities, etc.)	$ 20,000

Supplementing the community benefits of the operating budget, Petrogas for a number of years, has returned a capital budget which has averaged in excess of $3,000,000, annually. Again, the major portion is expended in Calgary or in the province generally.

The company policy on capital expenditures has been to utilize to the extent possible Alberta and Canadian made equipment for the plant and field facilities. The Canadian content of the plant is high, in the order of 90 percent.

A similar policy exists with regard to engineering, contracting, and consulting services. Local specialists are used almost exclusively to supplement the staff as required.

Petrogas, as a pioneer Canadian exporter of sulphur to off-shore markets, has contributed considerably to the national balance of payments, the transportation systems and the port facilities at Vancouver, having shipped approximately four million tons of sulphur by year-end 1972. The freight rates for sulphur during this period have varied between six and ten dollars per ton.



CANADIAN OCCIDENTAL PETROLEUM

PETROGAS PROCESSING LTD.

AIR QUALITY MONITORING STATIONS

FIGURE No. 4a

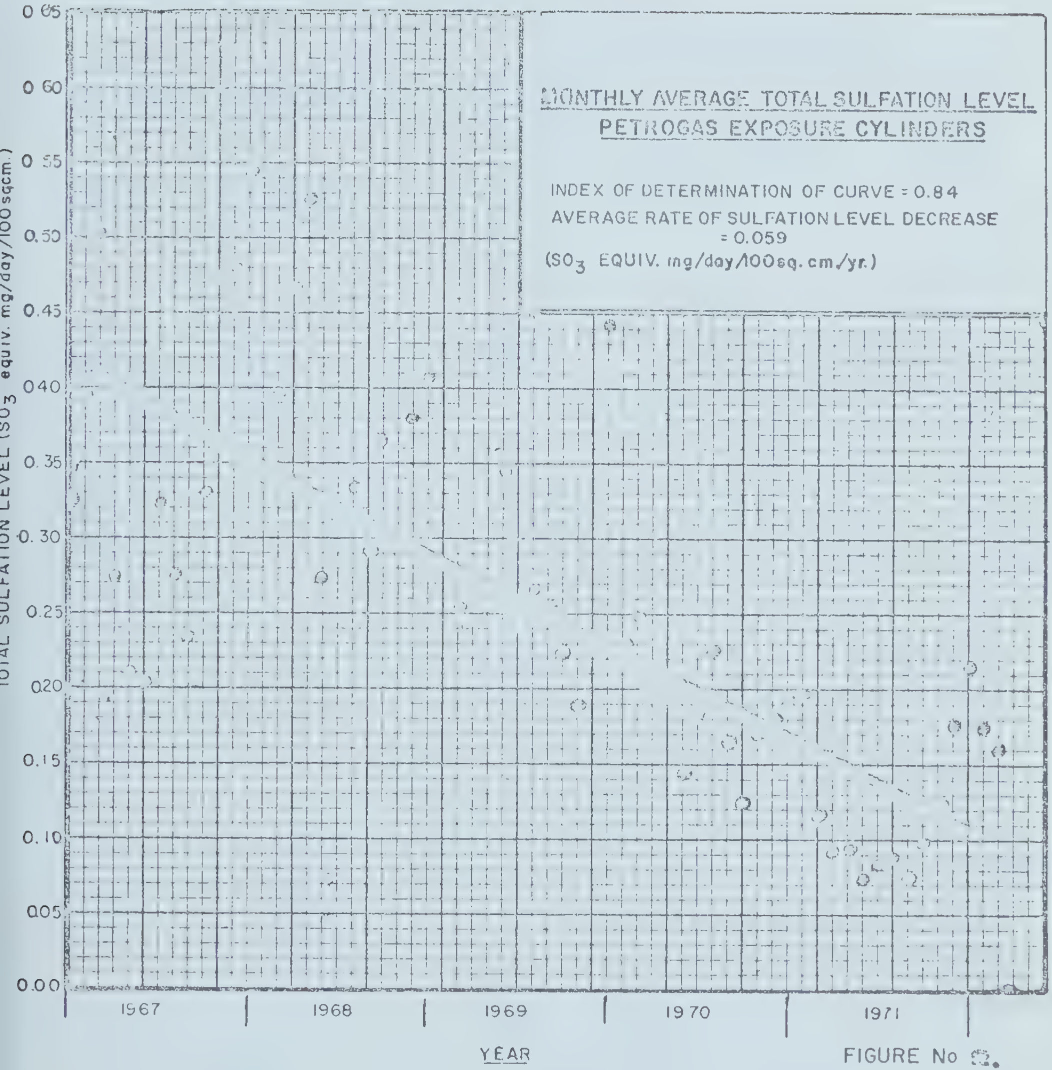

MONTHLY AVERAGE TOTAL SULFATION LEVEL
PETROGAS EXPOSURE CYLINDERS
INDEX OF DETERMINATION OF CURVE = 0.84
AVERAGE RATE OF SULFATION LEVEL DECREASE = 0.059
(SO3 EQUIV. mg/day/100 sq. cm./yr.)
TOTAL SULFATION LEVEL (SO3 equiv. mg/day/100 sqcm.)
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1967
1968
1969
1970
1971
YEAR

FIGURE No 2.

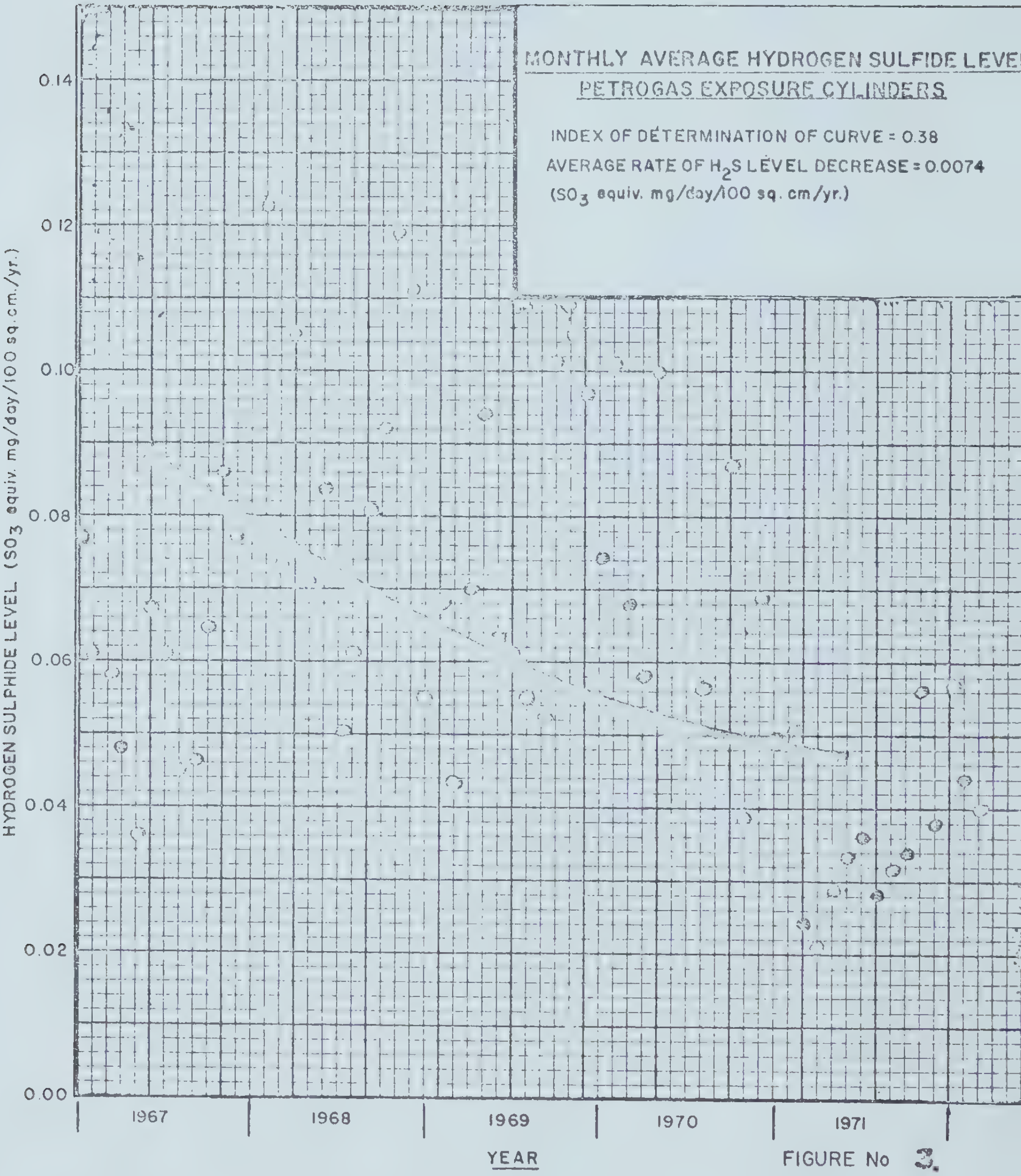

MONTHLY AVERAGE HYDROGEN SULFIDE LEVE
PETROGAS EXPOSURE CYLINDERS
INDEX OF DETERMINATION OF CURVE = 0.38
AVERAGE RATE OF H2S LEVEL DECREASE = 0.0074
(SO3 equiv. mg/day/100 sq. cm/yr.)
HYDROGEN SULPHIDE LEVEL (SO3 equiv. mg/day/100 sq.cm./yr.)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1967
1968
1969
1970
1971
YEAR

FIGURE No 3.

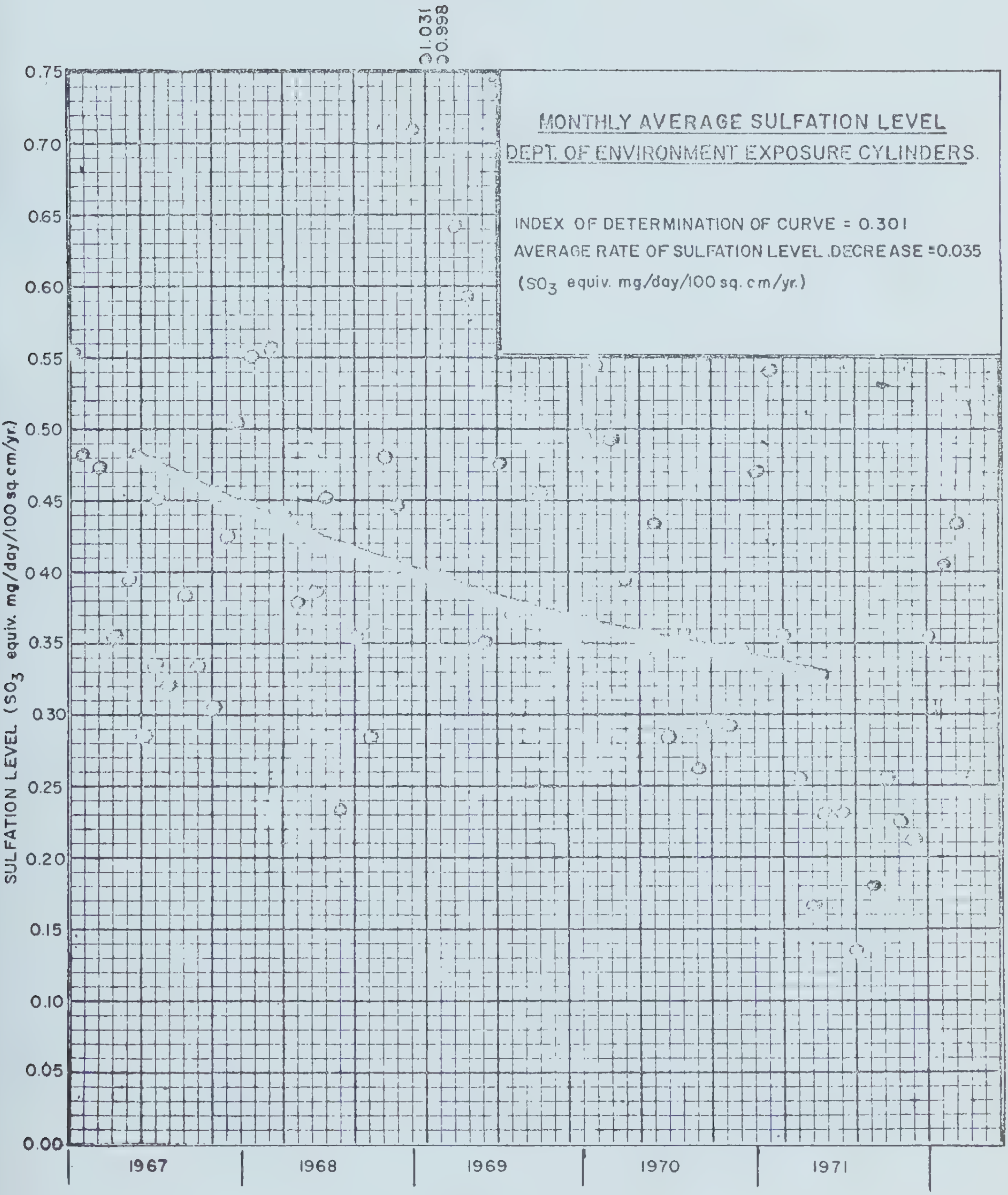
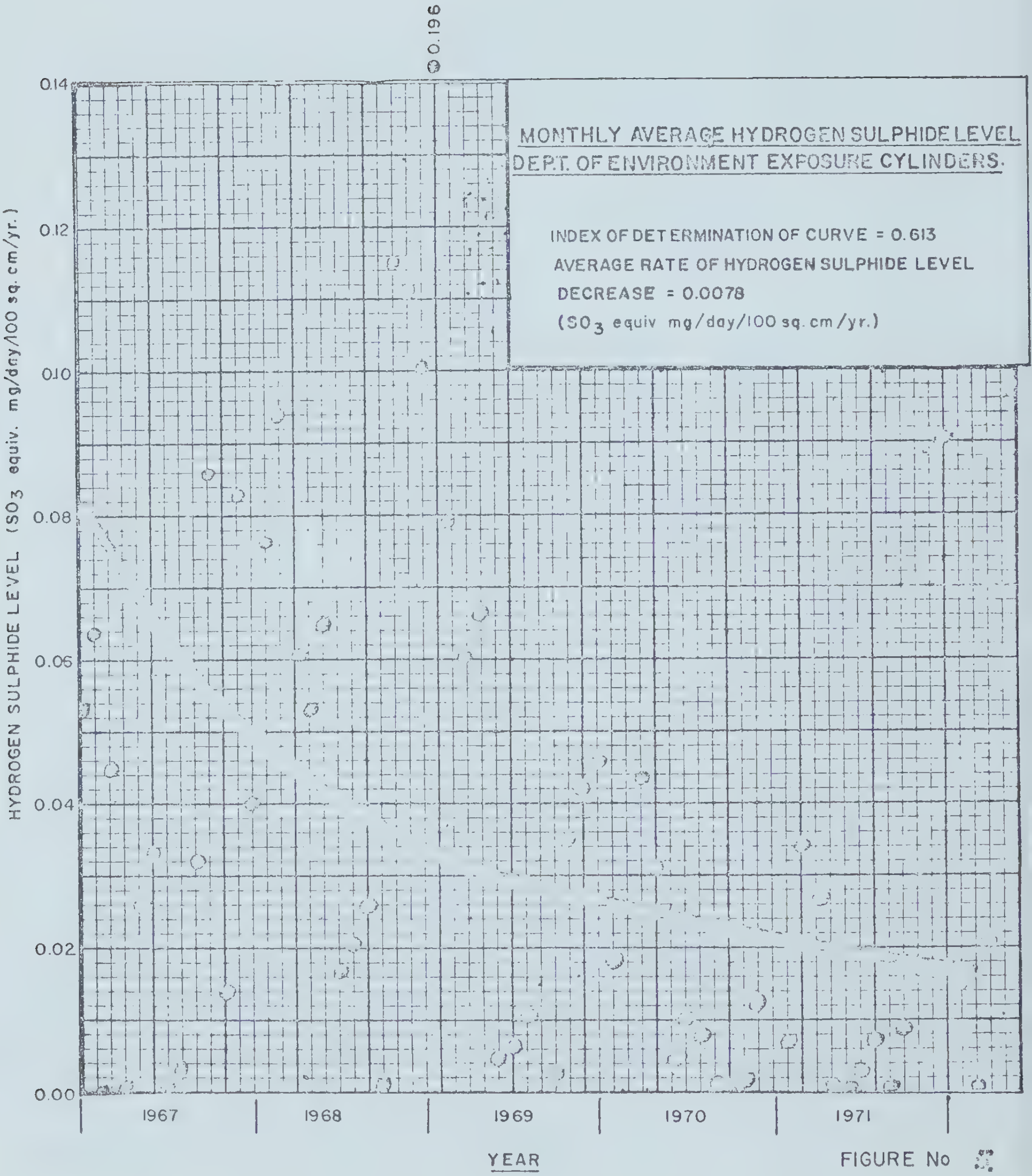

1.031
0.998
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SULFATION LEVEL (SO_3 equiv. mg/day/100 sq.cm/yr.)
MONTHLY AVERAGE SULFATION LEVEL
DEPT. OF ENVIRONMENT EXPOSURE CYLINDERS.
INDEX OF DETERMINATION OF CURVE = 0.301
AVERAGE RATE OF SULFATION LEVEL DECREASE =0.035
(SO_3 equiv. mg/day/100 sq. cm/yr.)
1967
1968
1969
1970
1971
YEAR

FIGURE No 4



MONTHLY AVERAGE HYDROGEN SULPHIDE LEVEL DEPT. OF ENVIRONMENT EXPOSURE CYLINDERS.

INDEX OF DETERMINATION OF CURVE = 0.613
AVERAGE RATE OF HYDROGEN SULPHIDE LEVEL DECREASE = 0.0078
(SO_3 equiv mg/day/100 sq. cm/yr.)

FIGURE No

TABLE 9.

ATMOSPHERIC CORROSION STATIONS

PETROGAS PROCESSING LTD. GAS PLANT

CORROSION RATE, MILS PER YEAR

CORROSION STATION NUMBER	EXPOSURE TIME DAYS	TELEPHONE WIRES (6) MIL	CDN BARBED WIRES (3) MIL	JAP. BARBED WIRES (3) MIL	GALVANIZED STEEL STRIP MIL	MILD STEEL STRIP MIL
1	1233	0.06474	0.28300	--	0.04000	0.47961
2	1238	0.08211	0.18044	--	0.03365	0.60166
3	1238	0.29592	0.07129	--	0.02362	0.32546
4	-----	-------	-------	----------	-------	--------
5	852	0.03973	0.05087	0.39932	0.03252	0.50570
6	852	0.03846	0.05284	0.03897	0.01246	0.55071
7	1299	0.04743	0.02704	--	0.01422	0.44652
8	1233	0.03958	--	--	0.01449	0.31518
9	1238	0.02795	0.02361	--	0.02413	0.27321
10	913	0.03557	0.11656	0.03797	0.01093	0.35288
11	913	0.03761	0.13578	0.03846	0.01265	0.27037
12	852	0.03219	0.05586	0.03470	0.01324	0.38106

TABLE 2.

MILS PER YEAR PENETRATION OF THE METALS OR ALLOYS AT THE VARIOUS SITES
(BASED ON WEIGHT LOSS)

METAL AND ALLOY	TIME PERIOD	OTTAWA	SASKA-TOON	MON-TREAL	HALIFAX Industrial	HALIFAX Residential	NORMAN WELLS	ESQUI-MALT	TRAIL
Aluminum-Alclad 3S	1 year	0.012	0.005	0.008	0.73	0.021	[illegible]	0.003	0.015
" 57S	1 year	0.011	[illegible]	0.027	0.48	0.014	0.003	0.004	0.014
" " 65S	1 year	0.014	0.005	0.033	0.54	0.013	0.005	0.004	0.017
" " 3S	2 years	0.010	[illegible]	0.036	0.60	0.014	0.002	0.003	0.016
" " 57S	2 years	0.014	[illegible]	0.029	0.43	0.015	0.005	0.008	0.016
" " 65S	2 years	0.010	0.005	0.009	0.42	0.016	0.004	0.003	0.015
Mild Steel	1 year	1.3	[0.76	1.6	4.6	1.8	0.045	0.54	-
	1 year	1.1	0.70	1.4	3.9	1.6	0.023	0.51	1.4
	2 years	0.9	0.60	1.3	3.5	1.4	0.020	0.47	-
Galvanized Steel	1 year	0.036	0.007	0.131	1.04	0.109	0.015	0.019	-
	1 year	0.033	0.025	0.123	1.20	0.085	0.015	0.022	0.082
	2 years	0.060	0.030]	0.136	1.03	0.097	0.014	0.018	-
Steel Alloys									
Low Alloy Residual	1 year	1.1	0.77	1.9	4.0	1.4	0.0	0.45	2.0
Copper Bearing	1 year	1.1	0.51	1.9	3.8	1.4	0.0	0.47	1.9
Copper-Nickel Bearing	1 year	0.8	0.51	1.4	2.8	1.0	0.006	0.41	1.3
Low Alloy Residual	2 years	0.9	0.50	1.3	2.9	1.2	0.005	0.41	1.3
Copper Bearing	2 years	0.8	0.62	1.2	3.0	1.1	0.0	0.38	1.3
Copper-Nickel Bearing	2 years	0.6	0.42	0.22	2.0	0.9	0.025	0.34	0.88
Stainless Steel Type 302	1 year	0.0	0.0002	0.0003	0.0216	0.0005	0.0	0.0005	0.0021
" " " 430	1 year	0.0007	0.0006	0.0003	0.0097	0.0003	0.0	0.0	0.0
" " " 316	1 year	0.0003	0.0005	0.0005	0.0123	0.0007	0.0007	0.0007	0.0011
" " " 302	2 years	0.0001	0.0	0.0001	0.0183	0.0003	0.0	0.0004	0.0002
" " " 430	2 years	0.0001	0.0	0.0	0.0492	0.0003	0.0	0.0002	0.0002
" " " 316	2 years	0.0002	0.0001	0.0243	0.0133	0.0030	0.005	0.0010	0.0010
Magnesium Alloy AZ80	1 year	0.142	0.0	0.724	3.18	0.308	0.127	0.0	0.526
" ZK61	1 year	1.01	0.921	1.94	4.60	1.69	0.309	1.70	1.87
" AZ80	2 years	0.284	0.157	0.75	3.64	0.432	0.049	0.142	0.702
" ZK61	2 years	1.04	0.63	1.72	4.44	1.69	0.440	1.84	1.69
Rolled Zinc	1 year	0.045	0.025	0.110	0.916	0.076	0.014	0.027	0.082
	2 years	0.047	0.017	0.114	0.851	0.067	0.009	0.020	0.074

[ ] - stations comparable to those in the Petrogas area

TABLE 3.

CORROSION RATE, MILS PER YEAR

ALBERTA REFERENCE CORROSION STATIONS

1971 - 1972

LOCATION NUMBER	TELEPHONE WIRES (6) MILS	CDN. BARBED WIRES (3) MILS	JAP. BARBED WIRES (3) MILS	GALVANIZED STEEL STRIP MILS	BARE STEEL STRIP MILS
CALGARY	0.03052	0.04859	0.04035	0.01450	0.39387
CALGARY	-	0.08598	0.01272	0.02141	0.41822
COLD LAKE	-	-	-	0.01594	0.16498
COLD LAKE	0.01019	0.08528	0.04522	0.01500	0.15542
EDMONTON	-	0.04035	-	0.00914	0.24922
KANANASKIS	0.01141	0.03691	0.00572	0.01576	0.21848
KANANASKIS	0.01156	0.03656	0.03334	0.02919	0.16542
LACOMBE	-	0.04779	0.05225	0.03129	0.56583
LACOMBE	0.01543	0.06114	0.03809	0.03581	0.58935
LETHBRIDGE	0.02206	0.03767	0.04206	0.01911	0.18833
LETHBRIDGE	0.08298	0.03146	-	0.03388	0.14254
SUFFIELD	0.07375	-	-	0.01257	0.28562
SUFFIELD	0.00563	0.05495	0.04552	0.02800	0.27740

ATTACHMENT NO. 1

A REPORT ON CROP AND SOIL CONDITIONS IN A 30 SQUARE MILE AREA SURROUNDING THE PETROGAS PROCESSING LTD. PLANT AT BALZAC, ALBERTA.

— prepared for —

PETROGAS PROCESSING LTD.
Balzac, Alberta

— by —

The SIBBALD
GROUP

DIVISION OF
C. L. SIBBALD AGRI-BUSINESS LTD.
AGROLOGISTS — ACCREDITED APPRAISERS
640 Seventh Avenue S.W.
Calgary, Alberta T2P 0Y5

AUGUST, 1972

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   MA 526 - 1 through MA 526 - 63

2. True Color Air Photographs
   MA 528 - 1 through MA 528 - 63
3. Map of Soil Sample Sites
4. Soil Sample Test Results
5. 35 MM Kodachrome II Slides

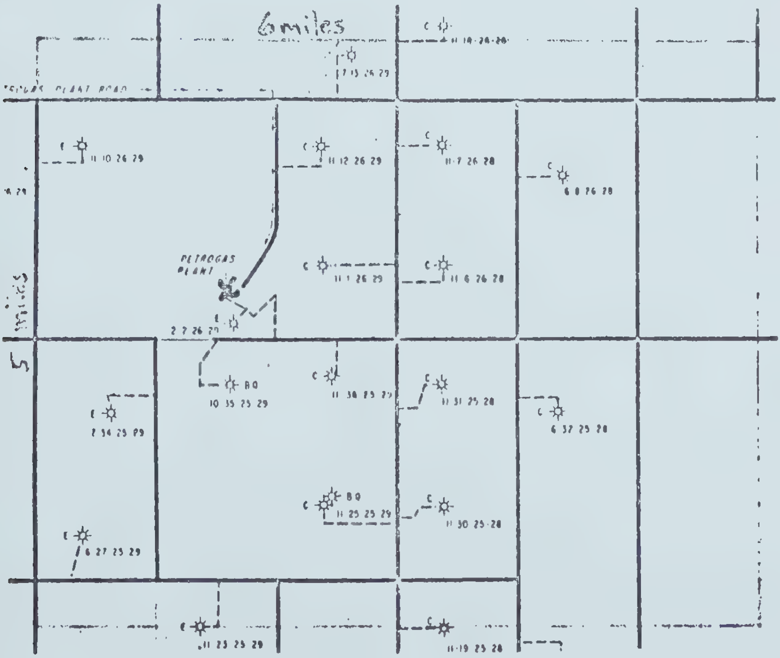
INTRODUCTION

On June 27, 1972 Machair Surveys Ltd., Calgary, Alberta took aerial photographs in false color infrared (film type 2443) and in true color (film type 397). Positive 9 x 9 transparencies were prepared and numbered as follows (See Exhibits 1 and 2 enclosed with this report):

Exhibit #1 I.R. photos MA 526-1 through MA 526-63

Exhibit #2 Color photos MA 528-1 through MA 528-63

During the week beginning June 11, 1972 Mr. Harold G. Hughes, agricultural technician with The Sibbald Group, Calgary, Alberta drew samples from a 30 square mile area surrounding the Petrogas Processing Ltd. plant which is located east of Balzac, Alberta. The soil sample sites and plant location are identified in Exhibit 3.



The soil samples were tested by Chemanal Laboratories Ltd., and their report dated June 23, 1972 is shown as Exhibit 4.

A preliminary letter dated June 27, 1972 by the Sibbald Group at the request of Petrogas which outlined preliminary interpretation of the soil test results.

The aerial photographs were inspected by Mr. Hughes who had also drawn the soils samples, and by Mr. C. L. Sibbald, agrologist. On July 11, 1972 both Mr. Hughes and Mr. Sibbald surveyed the 30 square mile area by car, and on foot, correlating the information observed in the aerial photographs with actual ground observations. At that time 35 MM Kodachrome II pictures were taken. These are shown as Exhibit 5 in this report. Some false color infrared photos were also taken during the ground survey, but these failed to develop because of a camera malfunction.

Following the ground survey, at Petrogas request, a preliminary letter dated July 18, 1972 was sent to Petrogas stating some of the major findings to that time.

Significance of Tests and Interpretation

Soil samples drawn from the same area grid and tested annually or bi-annually, represent, in our opinion, a most effective means of environmental control. The value of these soil tests is enhanced by the use of aerial and ground photographs, particularly when the aerial photographs are available at the time of the ground survey, as was the case in this instance.

The Sibbald Group
August 15, 1972.

AGRONOMIC GROUND SURVEY,
REPORT SUMMARY, AND
RECOMMENDATIONS

AGRONOMIC GROUND SURVEY

The 30 square mile area surrounding the Petrogas Processing Ltd. plant at Balzac, Alberta was inspected in some detail. Areas where specific stress to soil, crops or trees had been identified through soil test results or by air photo interpretation were visited. Additional 35mm color slides were taken at that time so as to enlarge upon the air photo interpretation. These color slides appear as Exhibit 5 to this report.

Damage to the soil east of the sulphur pile had been well documented with soil samples and air photo interpretation. Further attempts to gain additional information in this particular area was judged unnecessary.

In general, crops and soils in the region appeared normal. Some of the Exhibit 5 color slides show excellent crop growth (eg: slides 7, 8, and 19). Due to heavy rainfall, low spots were beginning to turn yellow because of too much moisture (eg: slide 19).

There was no evidence of crop damage which could be directly attributed to sulphur dust or from sulphur emitted in gaseous forms, except for that area already noted on NW 1-26-29-W4th, east of the Petrogas sulphur piles. Alfalfa, a crop that is particularly susceptible to acidification of the soil by excessive sulphur application, was growing extremely well in fields which have good farm management. Conifers in tree belts, some of which would be susceptible to heavy concentrations of SO_2, were also flourishing.

There were some potential problem areas noted through soil testing and air photo interpretation. These were visited, and the results of these investigations appear in the Report Summary which follows.

None of the soil and vegetative disturbances could be attributed to sulphur dioxide emissions.

SUMMARY OF JUNE 27, 1972 AIR PHOTO INTERPRETATION RESULTS			SUMMARY OF JULY 11, 1972 AGRONOMIC GROUND SURVEY	KODACHROME II COLOR SLIDES (See Exhibit 5)
Land Description	Air Photo Number	Remarks		
NW 9-16-28-W4	3	Several trees under stress, west side of N/S driveway, also one at east end of trees north of buildings and due south of buildings.	Cottonwoods; dieing from old age.	
SW 13-26-29-W4	8	Barren ditch running NE from well site.	Ditch is partly grassed down, other part is Canada thistles. The well site is not connected by any channel with this ditch, and cannot be contributing to any erosion that may be taking place.	Slide #7 (from well site, looking north; ditch runs diagonally across the photo).
N½ 12-26-29-W4	8	Drainage along well site access road.	Drainage problem cannot be associated with well site. This is a naturally low area, looking west to dugout.	Slide #6 (from well site road, looking west toward the dugout for cattle).
NW 1-26-29-W4	18	Damage from airborne sulphur dust (also see soil sample results).	Documented by soil samples and air photo 18. Growth of vegetation severely restricted on approximately 8 acres.	
SW 9-26-28-W4	24	Tree damage (stress showing only in the larger trees - may be due to age).	Cottonwoods; old and dieing from old age.	
SW 4-26-28-W4	29	Stressed and dead trees in N/S windbreak.	The dead trees are old cottonwoods, and bark has been removed by animals rubbing up against them. Cottonwoods die naturally at 20 to 25 years of age, and there are many dead trees of this kind in farm shelterbelts throughout Alberta. Treebelt of caragana and conifers running east/west on same land is growing very well.	Slide #5.
NW 36-25-29-W4	34	Bare ground N.E. corner of quarter.	Upper, crescent shaped bare areas identified as "misses" by the seeder. Large irregular areas are caused by farmer spraying for toadflax. (Confirmed Aug.11/72 in conversation with the farmer, Mr. Clifford Barker)	
NE 35-25-29-W4	35	Water east side of well site (drainage from site?) Defoliated area approximately 400' x 400'.	Air Photo #35 - well site, pocket of water east of it is within confines of well site fence.	
N½ 34-25-29-W4	37	Shows numerous pipelines in area, and from little to no vegetation over water line north boundary of section.	Noted from the ground. This is particularly noticeable in gravel areas through which the waterline has passed.	
SW 34-25-29-W4	41	Damaged area west of well site. Defoliant spread last year, okay now. Defoliated area for wellsite 400' x 400'.	Effect of some defoliant spread in earlier years, appears to be recovering now. Defoliated well site area is about 400' x 400'. Damaged area approximately 100' x 400' (1 acre) outside the well site area.	Slides #12 and #13.
NW 29-25-28-W4	47	Slight stress in farm shelterbelt.	Stress not noticeable from the ground.	
N½ 21-25-28-W4	53	Road widening - some damage areas.	Noted from the ground.	
NW 19-25-28-W4	57	Flooding north of well site. Defoliated well site area 400' x 400'.	The wellsite appears to have been located in a natural depression, subject to flooding. Northward flooding, though extending from wellsite, does not appear to have been caused by wellsite operations.	
S½ 26-25-29-W4	60	Horseshoe-shaped group of trees showing stress.	S.E. portion of the "horseshoe" group is stressed because of location on high, gravel, ridge. Moisture is lacking.	
NW 23-25-29-W4	61	Stressed area S.W. of well site. Well site area defoliation about 400'x400'.	Natural, low, area. Not caused by well site.	
SW 27-25-29-W4	62	Slight damage N. side and S.E. corner of well site. Well site area defoliation about 325' x 400'.	Defoliant probably caused this. Did not go outside leased area. Well site defoliation 325' x 400'.	

Recommendations

1. Liming should begin on the area to the east of the sulphur piles. Petrogas has converted to the "slating" process, and this will assist in keeping the sulphur dust to a minimum.

2. Small areas around wellsites may have suffered damage from defoliants applied by Petrogas. Greater care in its application is recommended.

3. Sulphur application to most farmland in the area appears beneficial. There is a good "buffer" between the crucial 6.0 pH stage at which alfalfa could come under stress, and the soil samples tested. Surveys involving soil testing and air photo interpretation should be undertaken at two to three year intervals as a precautionary measure.

4. Communications with farmers in the area should continue, so as to keep them up to date on developments, and allay their fears if possible.

BACKGROUND INFORMATION

Elemental Sulphur

Nyborg and Schurer [1/] document how excessive inputs of elemental sulphur affects the soil:

"How soils are acidified by sulphur dust

Elemental sulphur dust is generated during sulphur block crushing and loading operations at gas processing plants. Sulphur dust is blown by wind and subsequently deposited downwind from sulphur loading areas. Most of the sulphur dust is carried only a short distance downwind, and severe damage to soils is usually confined within a mile of the crushing and loading areas.

When elemental sulphur is added to soil certain soil bacteria (of the genus Thiobacillus)oxidize the sulphur to sulphuric acid as follows:

$$2S \pm 3O_2 \pm 2H_2O \qquad\qquad 2H_2SO_4$$

The rate at which sulphur is oxidized varies greatly from soil to soil and depends on such conditions as temperature, moisture, aeration, fineness of the sulphur deposited, and number of *Thiobacillus* bacteria present in the soil. The acidification reaction proceeds most rapidly when soils are warm, moist, and well-aerated. Rate of oxidation may be initially limited by number of bacteria, but after sulphur is deposited the bacteria soon build up to their maximum number. Finely-powdered sulphur is oxidized much more rapidly than coarse sulphur. Sulphur finer than 100 mesh may be oxidized about 50 times more quickly than sulphur

5 to 10 mesh in size. Lumps of sulphur (say greater than 1 inch in diameter) are oxidized very slowly until broken down in size.

Why acidification of soils harm vegetation

Most natural soils have pH values in the range of 6.0 to 8.0 which is suitable for good growth of the majority of plant species. Some very sensitive plants, such as alfalfa, do not grow well when pH is below 6.0, but most species grow fairly well at pH values down to 5.0 to 5.5. In the pH range of 5.0 to 5.5, the aluminum in soils, which is toxic to plants, starts to become soluble. Some plant species are much more tolerant than others to aluminum toxicity (and to other toxicities found in acid soils) and will grow after a fashion in soil as acid as pH 4. However, soils of less than pH 4 are essentially barren.

Oxidation of 1 or 2 tons of sulphur dust per acre will lower soil pH by about 2 pH units, and oxidation of more than 3 or 4 tons* will acidify most soils to less than pH 4 and will retard or prevent plant growth. The first effect of acidification is a change of species of plants growing on a soil to those most tolerant to acidity. If acidification continues, plant growth will gradually disappear altogether.

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* It is assumed the author means 3 or 4 tons "per acre".

Surface horizons of the soils in the general area under study are close to neutral (pH 7.0), and the subsoil horizons, deeper than 5 or 6 inches, have higher pH values sometimes up to 8.5. [2] A few tests have shown extremes of pH value on different soils in the area from pH 5.1 to pH 10.3. A built-in "buffer" against acidification often favours the situation around Balzac. As long as the pH of the soil does not fall to 6.0 or less, the most susceptible crop, alfalfa, will not be stressed. Cereal crops do not come under stress until a pH level of 5.5 or less has been reached.

---

[1] Nyborg, M. and Schurer, R.J., "Reclaiming Soils Acidified by Elemental Sulphur From Gas Processing Plants", University of Alberta, Edmonton.

[2] Soil Survey Report No. 12, "Rosebud and Banff", prepared by Wyatt and Newton (1943).

The corrective measure usually applied is to lime the soil. Applications over a period of time amounting to 2 to 4 tons of lime, incorporated into the soil, will raise the pH of soil from 5.5. to 6.5. Sandy soils generally require less lime than clay soils. The lime must be finely ground (most should pass through a 60 mesh sieve).

Sulfur Oxides

Walker [3/] reports that the annual deposition of sulphur in precipitation in Central Alberta was 2 to 4 pounds per acre in 1969. This amount, he states is similar to that found in non-industralized areas of Sweden which have about the same annual precipitation.

Walker further states: "the estimated total removal of sulphur in the plant growth harvested from the plots on soil LuW*for the period 1967-1969 was 4.4 pounds per acre....". He then concludes: "The present levels of sulfur oxides in the atmosphere in central Alberta would seem to be contributing insufficient sulfur to the soils of the area to eliminate the sulfur deficiency that exists, except perhaps where the deficiency is marginal."

3/ Walker, Donald R., "Emission of Sulfur Oxides into the Atmosphere and the Sulfur Content of Alberta Soils, Canada Department of Agriculture, Research Station, Lacombe, Alberta.

* "LuW" is a type of loam soil

High concentration of SO_2 are known to be phytotoxic (i.e.: poisonous to plants). At this stage, young leaves yellow, and this condition spreads to the whole plant, reducing its growth. Large-leafed plants, eg: sunflowers turn brown around the edges of the leaves.

Treshow [4] states "Sulfur dioxide enters the plant principally through the leaf stomata and passes into the intercellular spaces of the mesophyll, where it contacts, and is absorbed on, the wet cell walls (Thomas et al., 1950). Here it combines with water to form sulfurous acid and sulfate. If stomates were the only means of entry, or if sensitivity were solely a function of sulfur dioxide concentrations, a correlation might be expected between the size or number of stomates and the plant's sensitivity to sulfur dioxide. The greater the number of stomates, the more sulfur dioxide would be expected to enter. But no correlation has been disclosed between susceptibility and the number of stomata per unit area. Rather than implying that stomates are not important routes of sulfur dioxide access, this indicates inherent, physiological factors are still more important in determining susceptibility."

---

[4] Treshow, Michael, "Environment & Plant Response", Professor of Biology, Department of Biology, University of Utah

Treshow also states that, while the total sulfur content of the leaf might be expected to provide a measure of the degree of leaf contamination and an "index" of the amount of air pollution, such is not always the case. Not only has he found no quantitative relationship between exposure of a given species to SO_2 and the amount of sulfur in the leaves; he has also found that there is no relationship between the amount of sulfur and the degree of injury. He concludes that measurement of sulfur in leaves can be used only for general, and not specific, evidence.

Some researchers have found that injury increases when humidity is high and the nitrogen available to plants is low. Thus, damage may tend to be more severe in crops already "yellowed" by lack of nitrogen. Night-time damage is less severe than damage from an equal concentration of SO_2 released during the daytime.

Alfalfa is among the most sensitive species of broad-leaved plants. Chlorotic (yellowing) and necrotic (dead tissue) effects of SO_2 on alfalfa has been intensely studied by many researchers. Zahn5/ for example found "clover-type" fodder plants (which includes alfalfa) were most sensitive to SO_2; wheat, leafy vegetables (excluding cabbage), beans, strawberries and roses were moderately sensitive; and root vegetables and cabbage were the least sensitive. Cells in tissues accumulating the greatest amount of SO_2 lose their capacity to retain water. Tissues then collapse and dry out, under acute conditions.

5/ Zahn, R., "Effects of sulphur dioxide on vegetation - results of experimental exposure to gas," Staub. 23, 343-352(1961).

Katz,[6] working in British Columbia, ranked the native conifers as to susceptibility to SO_2. The most susceptible were western larch, Douglas fir, and yellow pine. Lodgepole pine had medium tolerance. Red cedar and junipers had the most tolerance.

Among the cereal crops, barley is highly sensitive and readily damaged by concentrations of 0.3 to 0.5 ppm SO_2. A bleaching of the leaf tip is the outward symptom.

There is one further, rather paradoxical, situation which requires added research. On such soils as those at Balzac, sulphur added can be expected to increase yields and protein content of forage crops. However, it is also suspected that added sulphur is related to "white muscle" disease in cattle. Tests have established[7] that a high proportion of the bromegrass, timothy, alsike and red clover samples collected from 59 soil sites in west-central Alberta had selenium concentrations low enough to affect animal health. Increased growth of these forage crops due to the use of sulphur fertilizers was thought to be the cause. The Alberta Department of Agriculture states [8]

[6] Katz, M. et al. "Effect of SO_2 on vegetation", N.R.C., No.815, Ottawa (1939).

[7] Walker, D. R., "Selenium deficiency in Alberta forage" Can. J. Soil Science, Vol.51. 506-508, Oct. 1971.

[8] Alberta Department of Agriculture, "Selenium Soil-Plant-Animal Relationship", prepared by Massey and Martin.

(1) "Studies carried out last year on soil fertility plots in the Innisfail area did not show any significant effect of sulfur on selenium uptake even where treatments included 72 lbs. of sulfur per acre. Levels of selenium in forage from this area are so low (10-30 ppb), however, that further reductions would be insignificant in terms of the animal. Walker has noted that the reduction was most pronounced where the selenium levels were above 100 ppb."

(2) "As mentioned earlier in the text, a selenium survey is being conducted to delineate potentially deficient areas in the Province of Alberta. This action was initiated at the 1970 meeting of the Advisory Committee of Feed Testing and will continue to accumulate several years' data."

TOPOGRAPHY AND SOILS

TOPOGRAPHY AND SOILS IN THE STUDY AREA

The topography of the area under study is level and undulating on the west and east sides, with the large N/S centre portion being gently rolling.

Except for a small area close to the N.W. corner of the study area which is "brown soil", the majority of the area is covered by "shallow black" soil, of either transported, unsorted material containing from few to many glacial stones, broken topography and numerous sloughs or - transported surface material which has been subject to past glacial sorting (subsoil, is unsorted) and with few to many stones (resorted glacial).

The "brown soil" zone in the area is a heavy Phase Loam, while the remainder is a loamy "shallow black soil". On this type of soil, the top 4" to 7" is topsoil, and supports agriculture. A small marshy flat is situated in the S.W. corner of the study area.

In the block of land under study there are some areas which have a variation in soil profile, including slight salinity and the presence of free lime in the lower depths. The major portion has "fairly good" to "good" drainage.

The soil capability rating for the area runs from "fair" to "fairly good arable" in the N.W. corner, through "fairly good" to "good arable" (major portion) to "good" to "very good arable" (along the eastern boundary of the study area). There is a small portion of "poor" to "fair" arable, in the vicinity of the S.E. corner.

SOIL SAMPLE TESTING AND INTERPRETATION

Sampling

Samples of soil were drawn from the 0" - 6" level in all cases, and in addition, in the south-west quarter of each section of land samples were also drawn from the 6" - 12" depth.

The 6" - 12" depth samples appear as the first 30 samples in the Chemanal Laboratories Ltd. report, which follows (Exhibit 4). These deeper samples were taken to determine whether soil pH and other factors tested were different at this depth than in the 0" - 6" depth.

Samples were tested by quarter-section. Two samples were taken in each quarter section; these were mixed to form a composite sample for testing. A copy of the work sheet follows, showing "X" for sample sites where 0" - 6" samples were drawn, and ⊗ where both 0" - 6" samples and 6" - 12" samples were taken (Exhibit 3).

An additional ten samples were taken to the 0" - 6" depth on NW1-26-29-W4th in an area immediately east of the Petrogas sulphur piles. A separate work sheet sketching the location of these samples follows.

Interpretation

1) 6" - 12" Samples: Normally higher pH levels, indicating the presence of lime, is found in the lower depths for this type of soil as recorded in Soil

Survey #12. This is confirmed to some extent by the 30 test samples taken in this survey. Most soil tended to be higher in pH at 6" - 12" depth than 0" - 6".

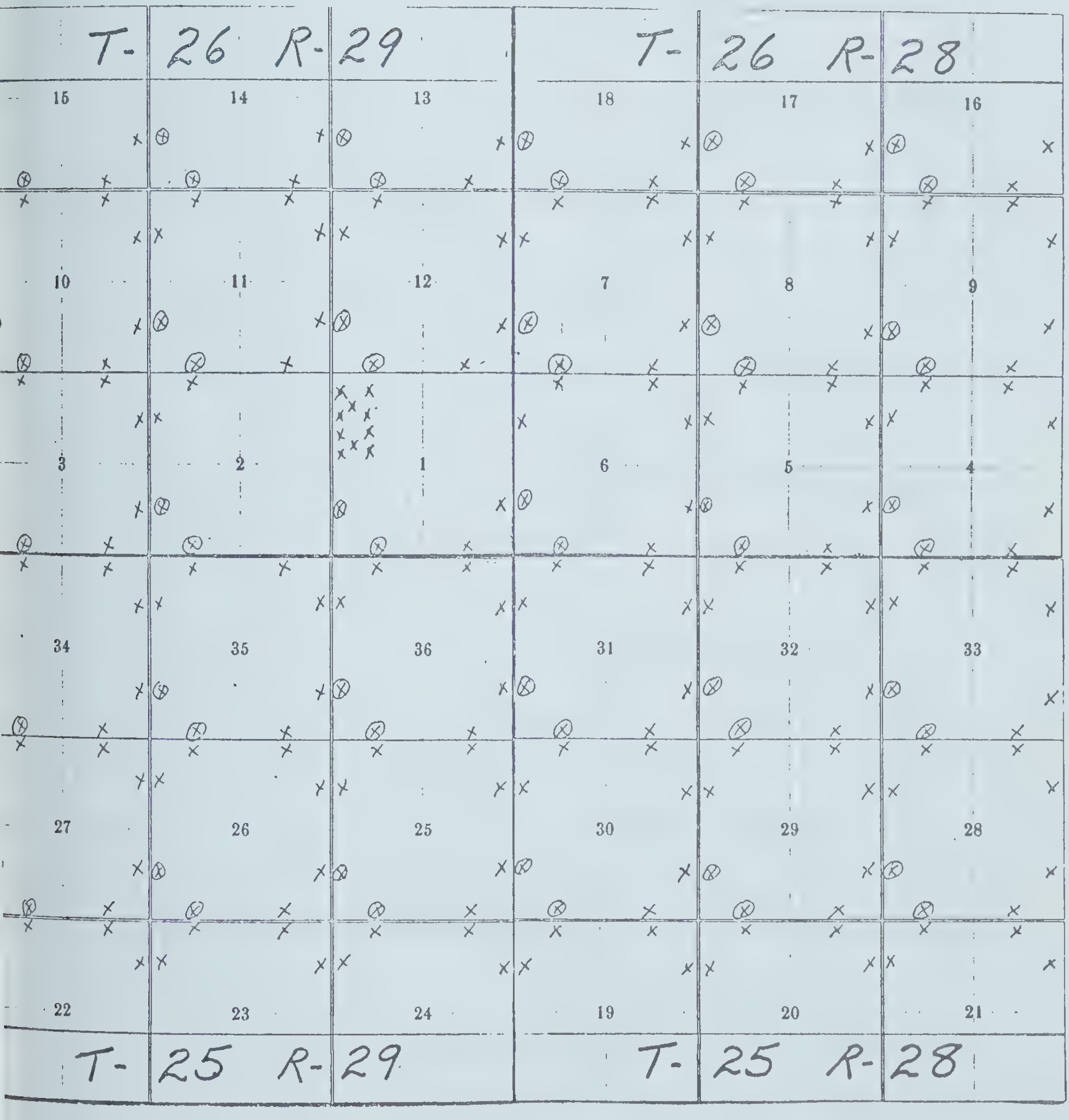
2) 0" - 6" Samples:

a) In samples taken throughout the study area, (excluding the ten samples in NW 1-26-29-W4th) it was not possible to detect any abnormalities. Some salinity was noted (See Exhibit 4 - conductivity of 5.0 or more) in a few samples, but this is to be expected. Humus content of the soil was generally good throughout. pH of the soil was normal, being within the range described in the official Soil Survey Report #12.

b) The main problem area occurred in samples P-6, P-8 and P-10, where the pH values are below normal. All of these samples were taken in NW 1-26-29-W4th (see sketch) close to the Petrogas sulphur piles. It is assumed that sulphur dust has blown onto this land and has caused acidification of the soil.

MAP OF SOIL SAMPLE SITES

Exhibit 3



6" - 12" core samples taken on the SW quarter of each of 30 sections marked ⊗ on maps.

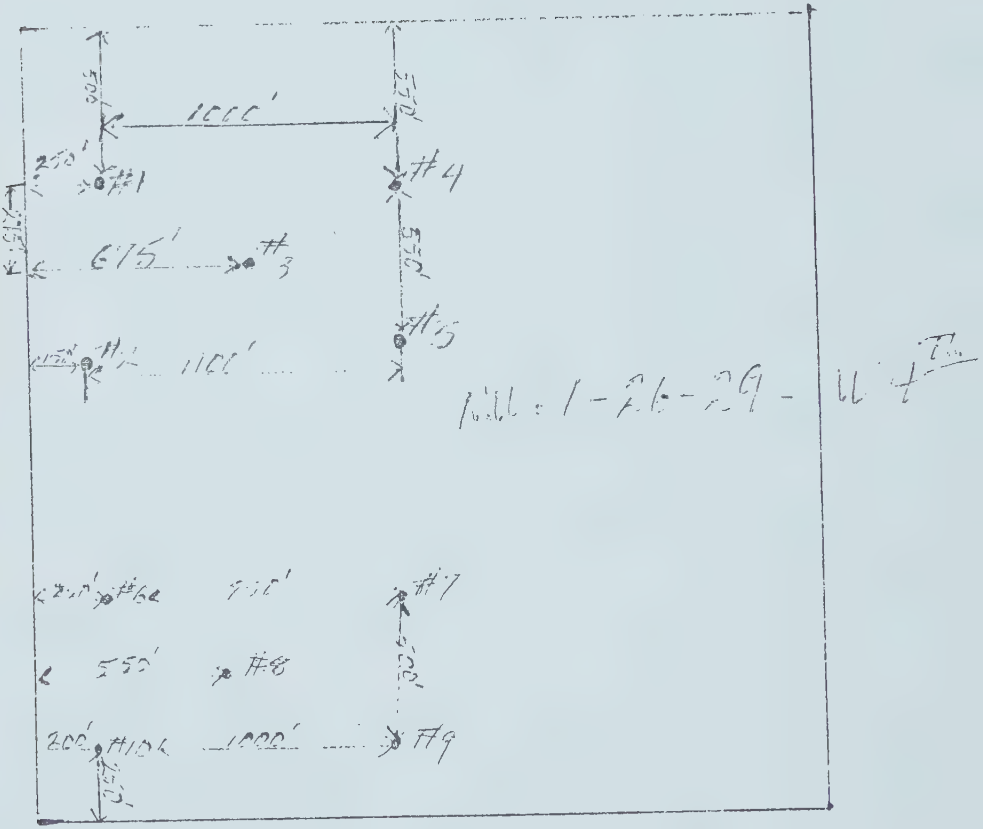
LOCATION OF 10 SOIL SAMPLES

NW¼ 1-26-29-W4thM

Taken June 8, 1972

Exhibit 3

Numbered #1 to #10



Measurements are approximate footage paced - not taped.

EXHIBIT 4

HEMANAL LABORATORIES LTD.
ANALYTICAL CHEMISTS

7060 - E FARRELL RD. S.E.
CALGARY 27, ALBERTA
PHONE: 255-6464

June 23, 1972.

Dr. C. L. Sibbald
Agri-Business Ltd.,
Calgary, Alberta.

Dear Dr. Sibbald:

Below is a brief outline of the methods used in testing the soil samples reported herewith.

SAMPLE PREPARATION - The samples were dried at 80°C, ground, and sifted through a 15 mesh screen.

X pH and CONDUCTIVITY - a 1:2 soil to water by weight mixture was used. The mixture was shaken for 30 minutes, allowed to settle, and the tests were conducted on the water phase. The actual conductivity measured was multiplied by two to make them comparable to University of Alberta soil tests.

HUMUS - The soil was re-dried at 80°C. 5 gm samples were placed in a muffle furnace at 375°C for 16 hrs. The sample was then allowed to dry in air, collect moisture, and was then re-dried at 80°C before weighing to determine weight of humus oxidized.

We feel it would be worthwhile to look at alternate methods for humus, since the above method can be in error by as much as ± 0.5% humus.

Sincerely,

N. J. Richards

EXHIBIT 4

HEMANAL LABORATORIES LTD
060 – E Farrell Rd. S. E.
algary 27   255 - 6464

ANALYTICAL REPOR

Date June 23, 1972

Agri-Business Ltd
640 - 7 Av SW
Calgary

Location	pH	Conductivity (millimhos/cm)	Humus (%)	Soil Type
SW 28-25-28 6"-12"	6.8	1.6	5.7	Dark Brown
29-25-28	7.0	5.2	6.7	Brown-Grey
30-25-28	7.8	0.69	4.6	Dark Brown
31-25-28	8.1	0.65	3.7	Grey
32-25-28	8.0	0.63	5.6	Light Black
33-25-28	7.8	4.9	3.9	Grey
5-26-28 *	7.4	1.5	5.6	Dark Brown
5-26-28 *	7.6	0.56	4.3	Brown
6-26-28	7.7	0.42	3.5	Dark Brown
7-26-28	7.5	0.75	7.2	Black
8-26-28	7.9	0.53	4.5	Dark Brown
9-26-28	7.3	3.3	3.8	Brown
16-26-28	6.6	0.38	5.3	Light Brown
17-26-28	8.6	1.6	3.6	Brown
18-26-28	7.7	4.2	4.4	Light Black
25-25-29	8.3	6.5	2.4	Grey
26-25-29	8.5	6.0	2.4	Grey
27-25-29	8.4	8.5	1.8	Grey
34-25-29	7.7	0.68	6.6	Black
35-25-29	8.1	0.60	4.4	Brown
36-25-29	9.5	4.9	2.7	Grey
1-26-29	7.6	0.70	8.3	Black
2-26-29	8.1	7.0	3.0	Grey
3-26-29	8.8	3.5	5.1	Dark Brown
10-26-29	9.0	2.6	3.7	Grey
11-26-29	8.4	2.2	4.5	Brown
12-26-29	8.4	0.75	4.4	Dark Grey
13-26-29	7.8	0.50	6.5	Dark Brown
14-26-29	8.2	0.63	5.8	Light Black
15-26-29	8.7	0.48	2.3	Light Grey
All above samples in SW quarter and from 6" to 12" depth				
* Both of these samples marked the same - one apparently should be 4-26-28				
NE 19-25-28	7.3	0.96	8.4	Black
NW	7.5	7.1	7.1	Light Black
NE 20-25-28	8.4	3.8	3.6	Grey
NW	7.7	1.3	7.4	Black
NE 21-25-28	6.8	0.64	7.3	Dark Brown
NW	8.1	1.2	7.7	Black
SE 28-25-28	7.3	0.55	6.6	Light Black
SW	7.2	1.1	8.0	Black
NE	7.3	0.75	5.4	Dark Brown
NW	6.8	0.36	9.6	Dark Black
SE 89-25-28	7.4	4.1	5.9	Dark Brown
SW	7.2	6.6	4.2	Dark Brown
NE	7.2	0.69	7.2	Black
NW	7.5	0.62	6.5	Light Black

ANALYST

EXHIBIT 4

HEMANAL LABORATORIES LTD
60 – E Farrell Rd. S. E.
lgary 27 255 - 6464

ANALYTICAL REPORT TO

Agri-Business Ltd

Date June 23, 1972

Location			pH	Conductivity (millimhos/cm)		Humus (%)	Soil Type		
SE	30-25-28		7.3	1.5		8.2	Black		
SW			7.5	0.59		5.9	Dark Brown		
NE			7.4	0.66		7.2	Light Black		
NW			7.7	0.79		7.8	Black		
SE	31-25-28		7.5	0.57		5.4	Dark Brown		
SW			7.6	0.60		8.0	Light Black		
NE			7.6	0.87		6.5	Dark Brown		
NW			7.2	0.88		9.6	Black		
SE	32-25-28		7.2	1.1		9.3	Light Black		
SW			7.5	0.58		6.1	Light Black		
NE			6.7	1.5		7.7	Black		
NW			7.1	2.2		9.3	Black		
SE	33-25-28		7.4	3.1		6.3	Light Black		
SW			7.3	2.9		6.5	Light Black		
NE			6.7	0.64		6.1	Light Black		
NW			6.8	0.42		5.2	Dark Brown		
SE	4-26-28		6.4	2.9		7.7	Black		
SW			6.7	0.62		8.1	Dark Brown		
NE			6.1	0.17		6.3	Dark Brown		
NW			6.6	0.34		6.3	Dark Brown		
SE	5-26-28		6.8	1.7		7.4	Black		
SW			6.4	0.87		7.1	Light Black		
NE			7.1	1.2		5.9	Dark Brown		
NW			6.7	0.69		8.7	Light Black		
SE	6-26-28		7.2	0.93		6.5	Dark Brown		
SW			7.3	0.72		6.8	Dark Brown		
NE			6.4	0.50		9.4	Black		
NW			7.4	3.3		7.9	Black		
SE	7-26-28		7.6	1.0		7.8	Light Black		
SW			7.1	1.2		9.8	Black		
NE			7.1	9.0		10.4	Black		
NW			7.2	0.88		9.5	Black		
SE	8-26-28		6.9	0.88		5.5	Dark Brown		
SW			7.2	1.1		5.1	Light Black		
NE			6.6	0.57		5.8	Light Black		
NW			7.6	1.2		8.1	Black		
SE	9-26-28		6.7	0.36		5.7	Light Black		
SW			6.6	2.2		7.4	Light Black		
NE			7.3	1.6		5.1	Light Black		
NW			6.4	0.70		6.0	Dark Brown		
SE	16-26-28		7.3	0.56		5.2	Light Black		
SW			6.5	0.33		4.9	Dark Brown		
SE	17-26-28		6.4	0.33		7.8	Dark Brown		
SW			7.1	1.6		8.4	Light Black		
SE	18-26-28		7.0	1.4		8.3	Black		
SW			7.4	2.5		6.4	Light Black		
NE	22-25-29		7.4	1.0		7.6	Black		
NW			7.4	0.93		6.5	Black		
NE	23-25-29		6.9	0.50		6.4	Light Black		
NW			7.8	3.1		6.2	Light Black		

ANALYST

EXHIBIT 4

CHEMANAL LABORATORIES LTD
7060 – E Farrell Rd. S. E.
Calgary 27 255 - 6464

ANALYTICAL REPORT T

Agri-Business Ltd

Date June 23, 1972

Location		pH	Conductivity (millimhos/cm)	Humus (%)	Soil Type
NE 24-25-29		7.2	1.1	6.1	Light Black
NW		8.0	3.0	6.2	Light Black
SE 25-25-29		7.2	2.4	5.5	Light Black
SW		7.2	2.5	6.5	Light Black
NE		7.4	1.0	6.2	Light Black
NW		7.1	4.1	6.8	Black
SE 26-25-29		7.0	1.4	5.3	Light Black
SW		7.2	2.5	5.3	Light Black
NE		7.7	1.5	5.3	Black
NW		7.6	1.0	5.0	Light Black
SE 27-25-29		7.2	1.5	6.4	Black
SW		7.1	11.5	5.2	Light Black
NE		7.2	1.4	7.6	Black
NW		7.1	0.87	6.0	Light Black
SE 34-25-29		7.3	1.0	6.0	Black
SW		7.0	0.93	8.7	Black
NE		7.8	0.70	5.4	Brown
NW		7.6	0.96	7.1	Light Black
SE 35-25-29		8.2	1.6	5.5	Light Black
SW		7.5	0.95	7.6	Light Black
NE		7.0	6.3	9.2	Dark Black
NW		7.7	1.2	5.4	Light Black
SE 36-25-29		6.6	0.76	9.7	Black
SW		7.8	3.2	5.0	Light Black
NE		7.3	0.84	5.8	Dark Brown
NW		7.9	6.2	5.0	Light Black
SE 1-26-29		7.0	0.74	9.3	Black
SW		7.4	0.93	9.7	Dark Black
SW 2-26-29		6.7	2.4	8.4	Black
NW		6.7	0.84	9.6	Dark Black
SE 3-26-29		7.9	1.3	3.9	Brown
SW		7.4	1.7	7.5	Light Black
NE		7.6	0.69	9.8	Dark Black
NW		7.3	0.64	9.4	Dark Black
SE 10-26-29		8.0	0.68	4.6	Grey
SW		7.8	0.95	7.0	Light Black
NE		7.2	1.1	8.8	Black
NW		7.7	0.35	3.2	Black
SE 11-26-29		8.4	1.8	4.8	Dark Grey
SW		7.6	1.0	6.8	Light Black
NE		7.3	0.81	7.5	Light Black
NW		7.6	1.2	8.0	Black
SE 12-26-29		7.5	0.84	7.1	Light Black
SW		7.3	0.86	5.3	Grey
NE		7.8	1.4	9.9	Black
NW		7.4	0.98	7.6	Black

ANALYST

EMANAL LABORATORIES LTD

EXHIBIT 4

ANALYTICAL REPORT TO

0 – E Farrell Rd. S. E.
gary 27 255 - 6464

Agri-Business Ltd

Date June 23, 1972

Location	pH	Conductivity (millimhos/cm)	Humus (%)	Soil Type
SE 13-26-29	8.1	1.7	6.8	Dark Grey
SW	7.4	1.0	10.0	Black
SE 14-26-29	7.9	1.3	6.0	Light Black
SW	7.7	1.0	5.9	Black
SE 15-26-29	7.8	1.1	5.4	Light Black
SW	8.0	1.1	4.6	Grey
P-1	8.1	2.7	10.2	Dark Black
P-2	7.4	1.3	12.8	Dark Black
P-3	7.5	0.94	5.6	Dark Brown
P-4	8.0	2.8	5.7	Dark Black
P-5	6.7	0.69	5.3	Dark Brown
P-6	4.6	4.7	3.8	Black
P-7	7.1	2.0	5.4	Black
P-8	5.0	4.3	6.3	Dark Brown
P-9	7.3	1.8	7.9	Black
P-10	8.1	3.6	6.6	Light Black

ANALYST

Brief submitted by C. Sibbald, Agri-Business Ltd.,
on behalf of
Petrogas Processing Ltd.

We have been engaged this summer in attempting to take a procedure which is called air photo interpretation principally using infrared false color air photography. As one person put it at one of the conferences, that it has been up to the past little while, something in the nature of "gee whiz" research. It's gee whiz look at those pretty picutres, and gee whiz I wish I knew what it was telling me.

Now, we have attampted to take this an extra step, and in conjunction with Mock Air Surveys Ltd., who did the flying, we did three things. We took soil tests of the area, thirty square miles around Petrogas Processing Plant Balzac. We combined an agronomist and a farmer and did a ground survey using the photographs as we went around. Finally we did the same thing on interpreting the air photos; that is, with the use of an agronomist and a farmer. For variations from the visual color to the infrared false color we used two kinds of film; we used the infrared false color and the S0397 film. We think that the soil sampling is very important, because of the upsurge of environmental conditions, and environmental testing. New laboratory tests are going to be devised in that the soil samples can be tested now, and kept and retested at future times. We're very high on having the practical type of people out in the field. In the case of our survey; a farmer can act in identifying objects and practices from photos. This would work equally well with woodland management in forested areas.

We are now using this same technique in land appraisals and in right of way arbitration cases. There are some limitations to this system. When we get a reflection of infrared we're getting a reflection which is only one cell thick. Therefore, if we take for example, the case of leaf rust which could become lodged in the area where the stem and the leaf of the plant join, where the humidity is high, this could be underneath our apparent viewpoint. Therefore, we have to use this with caution and hence the reason why we use the photos, but we also like to use the ground survey, and the soil tests as well. Sometimes what you see in a photo, shows up as stress but you're not sure of what kind of stress. That's another limitation. A third is that while we are gaining in our knowledge of this technique it still needs to be refined quite a bit. Seasons change and therefore your reflection of infrared changes with the seasons and it would also change with geographic areas as we will demonstrate here. However, it is a good control method and it is a fairly reasonable cost. Particularly if a bench mark is established, then it is done on an annual or biannual basis as some companies are doing and this is important.

I will just briefly go through this and then I will show you photographs which we selected out.* We sampled the soils on the week of June 11th and we tested them for pH, salinity and humus content. At the end of June the air photos were taken and the soil samples were compared with the soil survey No. 12, which is the standard for the area in question. They compared favourably except for an area which we will show you on the photographs where the sulphur was low in the vicinity of the sulphur piles. There were other things that we saw; dead trees in some farm shelter belts, stress on some other trees and bare areas in one field which we will show you. In an area adjacent to one of the well sites the soil sterilant had transferred into the crop. Also one of the water lines was exposed. We then did the ground survey on July 11th. We again flew another sector on August 25th and reinspected an area there. Our recommendations are very short.

We keyed in on alfalfa because alfalfa is the most susceptible to damage and particularly, excess acidity in the soil. Alfalfa is under stress from about 6.0 sulphur and down. In the district ambient air photos, the alfalfa appeared healthy as did the other crops. We recommended lining for the area east of the sulphur pile and as Mr. Chalmers has mentioned, the company has gone through it's slating process and perhaps the dust will be minimized from there. We could not relate any of the soil or vegetative disturbances which we saw, to the emission of sulphur dioxide. We recommended that defoliants and sterilants around the well sites should be used with more care and we recommended further surveys at two to three year intervals. We recommended that communication with farmers should continue so as to help allay fears. May I have the first slide please.

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*. The photographs referred to in this submission are available for viewing in the Information Center, Environment Conservation Authority, 9912 - 107 Street, Edmonton, Alberta.

This is the cloverleaf to the west of Balzac and the red reflection which you see is the good healthy crop growth. The redder the crop, the healthier it is in general. This is a crop of alfalfa on this side and here is Nose Creek and the green spots which you see are summer fallow. This is an area where a farmer has been working with his implements across that area, it appears darker as he has worked up the soil. The area of the sulphur piles and I think you can see quite clearly to the east, piles at the gas plant. This area which is supported in this case, it is Canada thistle. We killed the Canada thistle. Now the pH, in this area went down as far as 4.6 and this was the area that we were concerned about. Second slide.

Now you can see that is much darker. The area here is not as easy to define. This crop is barley and it has gone through the red stage and it has now almost matured, except for those few red or pinkish patches which you see there and that are almost entirely mature. The operator has worked over the field of thistles but they have come back on him, being persistent devils that they are. The pasture area which was originally a pale pink has turned to green. To the east of the plant is a shelter belt with a row of trees. There are individual trees that are white, indicating they are dead. The next group to them are red indicating that they are alive. We wanted to determine what was happening here and ground surveillance showed that we had a case where the big cottonwood trees with the age of about 20-25 years had matured and on some, the bark had been removed by animals rubbing up against them and so on. We had this dead area here and we had to establish the cause. The conifers growing were quite healthy and these are the things we were looking for in addition to some of the crop aspect. To assist us in doing this, the color photos of this same area were used as well and we can see those dead trees and the healthy growth of some of the rest of the shelter belt.

This is the edge of the plant site, again the same field, we were concerned with these bare spots. We wondered what was causing those. They didn't look natural to us and when we got out on the ground, we found that the farmer caused those himself. He had an infestation of toadflax and when you put implements on that land, you're directing the toadflax around, spreading it around, so he sterilized individual spots in his field. This was confirmed by the farmer himself. I mentioned earlier that we had some sterilant go over into cropped areas and this is shown here where the sterilant has been used for this square but it has tended to go into the crop just slightly and this type of photography brings it up very nicely.

This is another thing that is happening east of the plant, these 20 acre subdivisions all along here. The old farmstead is changing. You can see that there is a horseshoe of trees up here. On the one side they are more healthy than on the other. We wondered why, and when we got down on the ground we could see that the trees on the one side were up on a gravel ridge and had apparently not gotten as much moisture as the others. This by the way, is a road under construction.

Now we take to Brooks, Alberta and that is the horticultural centre. Some of the trees in this area are showing a pinkish shade and therefore we know they are under stress from some cause and the cause appears to be highly saline soil in that particular area. The other thing we wanted to show you was the bunches of flowers coming through. Some of them come through in the yellow range in their true colors.

This is the Brooks area before irrigation and the next one, is what happens with irrigation.

This is alfalfa taken August 26th, the lines in between are the irrigation ditches and the crop is growing very vigorously as you can see. There are patches which are not getting water and therefore you have areas that are not supporting crop growth.

Next, these are different kinds of crops and I'm putting this on simply to show you the different crops. We have for example. corn, sorghum, potatoes, carrots, cabbage, and parsnip. Each one of these crops is going to return a different color to us, then through the different steps in the year as well, and we have to get used to the different colors.

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

Mr. Chalmers, there are several points which you have raised that I feel have been very strongly made. More strongly made then in any of the three previous hearings and this one. I think that you have indicated without qualification that there are no significant effects, and from the information you presented we can accept that at face value for the moment. I would like to ask Mr. Sibbald a couple of questions with respect to that statement rather than you, because I think that he is more involved technically, but I would like to ask you, has the company, in the operation of the plant over the last 11 years plus, been faced with the necessity to invent its own technology to keep abreast of the increasing standards imposed by regulatory agencies?

MR. W. CHALMERS

Yes, we have very much so. We have developed our own instrumentation systems to maintain or obtain a closer control on sulphur plant operations and in certain respects the gas leaking operations. The technology was just not available in the world.

DR. S.B. SMITH

To carry that a step further, was the research that resulted in the invention of this technology Canadian research and is it patented or does it still reside in Canada?

MR. W. CHALMERS

It still resides in Canada. We have not done anything in regards to patenting it. Most of the equipment that we used for this was shelf items, and it was a result of thinking mainly among ourselves plus the tremendous experience factor which we had applied. To get into the final details we had a contractor supplement our own staff and bring in some of his thinking, so this made it an extremely difficult thing to patent and we just didn't carry it forward on that basis.

DR. S.B. SMITH

There was a Canadian research carried out here.

MR. W. CHALMERS

It was local research.

DR. S.B. SMITH

With regard to the industry and the public, and aside from the context of farmers or others residing in the immediate area of the plant, does the company meet on a regular or an irregular basis with citizen groups or take part in similar situations?

MR. W. CHALMERS

No. We have not made a habit of doing that prior to the petrogas operations being started. A meeting was held in Airdrie where the hopes and aspirations of Petrogas Processing Limited were presented to the citizens of the community at large and it was a well-attended meeting. I think everyone in the area came down to hear that, and from then on we had very little problem with the local population. We have been very fortunate in having very few complaints, and in fact we have had more information than complaints. If there has been anything unusual they have called up and advised us, not with complaining attitude but more with an informational attitude, and I think that this typical approach of leaning on the fence and talking to the farmer or stopping on the road and having a word with him has carried us over the years without any problems.

DR. S.B. SMITH

The use of infrared false color, I am sure, you are aware has expanded very rapidly in the last four or five years, particularly in dealing with vegetal cover species and concentrations of the plants. As you indicated it is essential to establish a ground control transect to give you a read-out on what you are actually picking up in the camera work. Is this true?

MR. C. SIBBALD

We believe so, yes.

DR. S.B. SMITH

These photographs cover about 30 square miles and are done at relatively low altitudes. From the picture they don't appear to be very high, so that you are presumably getting good resolution of the reflection, but I am not concerned with what you are getting on an instantaneous basis because that is what a picture gives you, but what you are getting on a trend basis. Have you set up a statistical design in this kind of research to randomize plots around the area that you can compare specifically within this rather small area of 30 square miles as a matter of control? If so I wonder if you could explain what kind of statistical approach you have taken to randomizing the data to try to establish trends, because from what you have said there are no gross acute affects but their may be some chronic effects that we are not aware of.

MR. C. SIBBALD

Answering the first question, no. We have not set up any specific plots. This work with petrogas is in its early stages and we have attempted this year to establish a base from which to operate. From that point on it is up to the company what they do. There has been some good plot testing work done by the University of Alberta, Dr. Marvin Nyberg in particular. With regard to the over spill of sulphur dust from the sulphur pile, this is fairly well documented. The lining is a fairly simple process that has been carried on in parts of Canada, the East and in Europe for a number of years and we are pretty well aware of what this can do. The other area which you are most interested in is the long-term effects of sulphur dust. There has only been sporadic research in this and Dr. Walker at Lacombe has demonstrated that much of the sulphur falling on the soil is possibly going to be taken up by the plant and taken out of the soil. As far as statistically analyzing this thing, I am not convinced yet that we are going to find anything more than we have already found in that regard. Before going to that kind of expense I would like to determine if we do have some damage caused, say, by flash amounts of

SO_2 hitting the plant. I would like to see that there is actually damage of that kind before we say it is necessary to get into the long-range effects.

DR. S.B. SMITH

Are you aware of any soil microbiology or work that is being done in the vicinity of the plant?

MR. C. SIBBALD

No, I am not.

DR. S.B. SMITH

According to the data that are available, SO_2 concentration in the atmosphere is much lower then one would expect from making assumptions and calculations over the last 100 years as to what may have gone into the atmosphere. This would suggest a biological or biochemical sink which is pulling SO_2 out of the air as it enters, because it is considerably heavier than air. It must come down. This is the reson I ask about the soil microbiology. It has been suggested, or stipulated at least, that there may be biological systems. Are you aware of any work that is going on in this regard?

MR. C. SIBBALD

No, I am not. Dr. Walker in Lacombe has, I beleive, tried to measure the sulphur coming out of the atmospere in precipitation, but in the soil I have not heard of any.

MR. W.A. FLOOK

Mr. Chalmers, you stated that you are storing sulphur in slated form at the plant. Would you like to tell us how long a period of storage is involved in the slated form?

MR. W. CHALMERS

Our slated facilities are specifically designed for the unit train movement to Vancouver. Our stock pile of slates at any point in time will not exceed 15,000 tons. This is equivalent to three unit trains and it is designed on a make-up capability. It would take us three days to make up a unit train and it is a compromise situation.

MR. W.A. FLOOK

During this period have you noticed any increase in the tendency to dust?

MR. W. CHALMERS

No, we are moving it out fast. We do have a certain amount of breakage during the looking into the cars, and things like that. This happens intially when the slates drop into the steel hoppers; after this you do have some flakes in the bottom.

MR. W.A. FLOOK

The other thing that I was interested in is the sulphur limit, the ground level concentration that you quote as being the one to which you must adhere, 0.15 ppm for 15 minutes. This is considerably tighter than the ambient air quality standard for your area.

MR. W. CHALMERS

This is correct. Generally the ambient air quality in a area similar to the Balzac area would be 0.2 ppm. In the forested areas further north it would be 0.3 ppm and out in the bush area it would be 0.4 ppm.

MR. W.A. FLOOK.

I believe that is for a longer period?

MR. W. CHALMERS

Yes, for a much longer period.

MR. W.A. FLOOK

Is there any reason for an imposition of these much stricter standards?

MR. W. CHALMERS

No, our stacks were originally designed for this. When we design the expanded plant in 1966 we tried to correct a number of problems that we had, and we built these two stacks to have a grand level of 0.15 ppm.

MR. W.A. FLOOK

In other words you are saying that the limit to which you must adhere was based partly on your capability to comply with it?

MR. W. CHALMERS

That's it.

MR. W.A. FLOOK

The better the plant you are going to have the tighter the limits are going to be. Is that it?

MR. W. CHALMERS

Yes.

MR. W.A. FLOOK

You also indicate that you see little practical limit to the potentiality to the Claus system. Have you any idea or would you like to suggest up to what level you think the Claus will go ultimately?

MR. W. CHALMERS

I would like to think that we can get up to 98 per cent and be in that range. We have listed our own operation 3 per cent of points in a period of 20 to 24 months and we don't think that we are at the end yet.

DR. W.R. TROST

Mr. Sibbald, in your soil testing did you test for any specific elements or compounds?

MR. C. SIBBALD

No.

DR. W.R. TROST

Now, in the infrared photography method, how much damage or how much change in a crop for some stress reason is necessary to make a difference in photography?

MR. C. SIBBALD

It is going to depend on the type of stress that you are talking about. You could have a very dry season which would stress the crops very quickly, possibly some time in June. The other things that could effect it would be disease organisms, for instance, not something that necessarily would kill the crops but would appear, for example, as some kind of leaf blight which would start to retard it, I don't know if you can, at this time, pinpoint a time or an amount of stress which would cause a change.

DR. W.R. TROST

Can you make any correlation between the stress and the change that you measure and the ultimate result of that change in terms of yield or productivity?

MR. C. SIBBALD

I think that you could only be coming back to Dr. Smith's question, that is if you start seeing these crops under stress then I think you would go to a plot-testing method to measure yield.

DR. W.R. TROST

Is that kind of testing being done on any crop for any particular stress so that you do make a correlation in experimental setting as against damage of productivity?

MR. C. SIBBALD

Not that I know of. They may be doing it in some of the University of Alberta work now, but originally the measurements on this elemental sulphur dust from the sulphur piles were done just on a type of response basis. It was not measured with infrared, as far as I know.

DR. W.R. TROST

The kinds of effects that infrared photography measures are limited to plants. Is that correct?

MR. C. SIBBALD

Soils as well. There is some research going on now which gives you some idea of the soils through the plant, in other words, your soil nutrients and things like this.

DR. W.R. TROST

What kinds of environmental effects would not show up in this method?

MR. C. SIBBALD

Certainly, very minute quantities of things may not show up, such as diseased parts of the plant which are hidden from view underneath--and very often this is where diseased parts occur because there is a microclimate there which is of very high humidity and diseases get established underneath leaves. There could be others, but those are two examples I can think of.

DR. W.R. TROST

Effects on animals would not show up?

MR. C. SIBBALD

They wouldn't show up, but there has been some research about helping and unhelping animals and again I would imagine that the animal would have to be rather ill before something would show up, so I think the asswer is 'no' at the moment.

DR. W.R. TROST

Corrosive effects?

MR. C. SIBBALD

I would doubt it.

DR. W.R. TROST

How would you interpret what you showed us through the pictures in respect of that field that was able to grow thistles on one part and wasn't growing crops? Was that crop not planted or were the thistles more....

MR. C. SIBBALD

I didn't talk to the farmer himself, but I presume he has been leaving this field in fallow year after year and he wanted to work it and get the thistles out, possibly even use his own herbicides on it. At one end of the field the pH level had gone below 5.0 in some places, which is quite acid, and the thistles could not complete with that kind of acidity. Further down the field, the thistles, being very hardy, were able to keep coming on.

DR. W.R. TROST

In that kind of a situation, in which coditions make it possible for one kind of plant life to flourish but make it difficult for other kinds of plant life, perhaps, there is plant life but there has been a substitution would this method of infrared photography be able to make a contribution?

MR. C. SIBBALD

Yes, I think so, if this is an area.

DR. W.R. TROST

It would be a little more skillful and a little more skill testing, and you would have to be more careful on the color. Is that right?

MR. C. SIBBALD

That's right. These are the things on which we have probably progressed from gee-whiz research up to the present, but there is still some refining that has to be done, and some of these subtle tone changes in the color are one area.

DR. W.R. TROST

Most of our province, particularly near the foothills, has prevailing winds so that you get wind plumes of a kind of configuration. Did you do a correlation between the directions of the prevailing winds and the possible incidence of sensitive areas as determined by your method?

MR. C. SIBBALD

No, I didn't. We generally leave this to the client and in his case he wanted to start out on this initial run with a 30 square mile area pretty well surrounding his plant. Other clients have requested, for example, that we take several miles further to the south of southeast, depending on the prevailing wind, and this may be a good practice.

DR. W.R. TROST

You would probably advise them to look in those directions to get the most likely areas?

MR. C. SIBBALD

Yes. It depends on the type of work they have been having done by other consultants.

DR. W.R. TROST

Mr. Chalmers, is Petrogas an independent company or is it a group running a group operation?

MR. W. CHALMERS

Petrogas is unique. A limited company was formed rather than the conventional unitized arrangements. It is a consortium of 24 companies having a Board of Directors and operating like any formal business company.

DR. W.R. TROST

Are some of the companies that have come together to form Petrogas companies that have gas sulphur extraction plants in other parts of the province?

MR. W. CHALMERS

This is correct. Most of the companies are also sulphur and gas producers, and they also have access to all the information Petrogas acquires or tends to acquire through an engineering committee.

DR. W.R. TROST

Then there will be an exchange of information on plant technology and things of that sort?

MR. W. CHALMERS

Very much so.

DR. W.R. TROST

Is there also an exchange of iformation among these companies in respect of the research they are doing on the environmental effects on these plants?

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

So you will have had some contact with the work done by Shell, for example, in the Pincher Creek Area?

MR. W. CHALMERS

Shell is not one of our group.

DR. W.R. TROST

So you did not have contact with that?

MR. W. CHALMERS

No. The industry itself is unique, though the gas processing industry--well, there is generally fairly free exchange of information, particlarly in problem areas.

DR. W.R. TROST

Are any of your companies among the companies operating in the Whitecourt Research Co-Operative Group?

MR. W. CHALMERS

Yes, there are.

DR. W.R. TROST

Do you have exchanges with them?

MR. W. CHALMERS

Yes, we do have communications through this engineering committee.

DR. W.R. TROST

Mr. Chalmers, what is the compostion of the gas to your plant at the well head?

MR. W. CHALMERS

Very generally we have three gas fields producing gas to the plant. It is the Crossfield gas which is a very thorough gas. It varies between 27-73% H_2S with CO_2. We also produce into the plant the Elktron and Basil quartz gases. They are quite similar with 1% H_2S and 10% CO_2. They are both very wet gases, condensate wet and we have significant LPG production from both the Elkton and Basil quartz. The Crossfield gas is a very dry gas so we process a very mixed gas.

DR. W.R. TROST

Do you try to get a fairly constant gas by mixing?

MR. W. CHALMERS

Yes, we do have a fairly constant gas. The H_2S content of the gas going into gas-fitting units usually averages about 16% H_2S.

DR. W.R. TROST

Does a very sour gas like the Crossfield gas give you any operational problems at the well head?

MR. W. CHALMERS

It did back in the early days. We have a very tight formation there and it was extremely difficult to produce the gas at the high pressure. We encountered a tremendous number of deposition problems of sulphur back in the formation and in the well bore itself. Each column in the well acted like an orifice and took a small pressure drop over that, and at the same time we dropped our sulphur and this continued all the way through the tubing. We had to develope certain techniques to produce that gas, but with time and the declinning pressure it seems to have considerably reduced the problems. On some days we couldn't keep a well on for a 24-hour period. Now we can keep wells on for months or more.

DR. W.R. TROST

This was elementary sulphur vapor?

MR. W. CHALMERS

This was elemental sulphur dropping out and just completely plugging the well bore.

DR. W.R. TROST

How would you handle that?

MR. W. CHALMERS

We eventually settled on a mixture of condensate and carbon disulphide to dissolve the plugging.

DR. W.R. TROST

Then you would bring that into solution and what would you do with the liquid material?

MR. W. CHALMERS

At that time the liquid material was brought back into the tanks at the well site and was trucked back to the central treating facility in the plant. Since 1969 we have been doing all well treatments like that. All the well effluent travels with the gas into the plant into a central closed facility for treating.

DR. W.R. TROST

Then you recover the carbon disulphide I suppose?

MR. W. CHALMERS

We recover everything, yes.

DR. W.R. TROST

I suppose there was some popular name for the truck that delivered that?

MR. W. CHALMERS

Yes. When you look at our submission you see a lot of these high H_2S and different spots on these charts through the earlier years of operation. This was particularly, with these trucks passing sulphuration stations which have cumulative, and once you put two or three on there in a month it really got quite ahead of you.

DR. W.R. TROST

Is it not a bit unusual to actually have elemental sulphur in the gas?

MR. W. CHALMERS

We don't have it.

DR. W.R. TROST

This particular problem might have been a difficulty in time past and is no longer.

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

Do you have any corrosion problems with htese very sour gases at the well head and in the pipeline?

MR. W. CHALMERS

No, we have been remarkably free of problems like that. We did have a number of initial problems in 1962. We lost two pipelines at that time. There just wasn't any technology available to help us along there and we did develope some inhibiting systems at that time which have carried out through to date. They are quite a bit more sophisticated but they are essentially still the same inhibitors we use today. These are deposited on the pipe in sort of a black mat finish and in minute quantities, but they provide all the protection we need. Each year we cut a section out of our main transmission lines and narrowing lines just to examine the state of the lines, and during the year we carry out ultrasonic inspection. This is an actual visual check where we take a section line out of service and cut a piece out.

DR. W.R. TROST

Is the inhibitor applied in the gas stage?

MR. W. CHALMERS

It's automatically applied in the gas stage at the well site.

DR. W.R. TROST

In the vicinity of the plant, that is on the site itself or adjacent to the plant, are there any indications or corrosion either as in the barbed wires rusting or in machinery not having its bolts too easy to move and so on?

MR. W. CHALMERS

Not generally. We have a number of corrosion stations in the plant area. We are working in an area in access of 200 miles, and we have quite a number of corrosion stations in this area plus a number of background stations which are located well outside the plant. The readings that we have from these corrosion station simulate farm instruments, paint, telephone wires and things like that, and indicate that we have no serious problem. Actually the last set of readings that we had indicated that conditions here are considerably superior to the residential or industrial areas of Halifax, Montreal or Ottawa, and the only area that you could say is close to our conditions would be Saskatoon. The readings that we had were just slightly less then the Saskatoon readings.

DR. W.R. TROST

Is that true of the past as well as the present?

MR. W. CHALMERS

We have been monitoring now for quite a few years. I think that we are in the fourth or fifth year of monitoring the environment, as far as corrosion aspects are concerned.

DR. W.R. TROST

In monitoring, do you use instantaneous recording devices?

MR. W. CHALMERS

For the ground level concentrations of H_2S we use continuing recording devices, but for corrosion stations we use specific samples that are located in certain areas, and these are collected manually over a two-year period and brought back. Our monitoring system for the environment itself consists of seven stations. The information on SO_2 at ground level from these stations is telemetered back to the plant site. Four of the moitoring stations also have continuous recording H_2S analyzers and wind instruments. We have a picture of what is happening at ground level over our level of operations. These stations were selected by the Energy Resources Conservation Board.

DR. W.R. TROST

Is this on an instantaneous and continuous basis?

MR. W. CHALMERS

This is on an instantaneous and continuous basis. It comes underground on telemetering wires by the Alberta Government Telephones, and is indicated in the plant control center. In the event of a high-level alarm we have certain procedures that we go through. These were prescribed by the E.R.C.B., whereby we immediately raise the stack temperature to an 1100°-1200° range and observe conditions. Then by having these instruments and the wind indication we can also do a fairly rapid calculation to see if the fallout area is actually coming from our plant. If we do come up against a situation where the cause is indicative of the gas problem we will pull back the plant and have the plant pull back the plant operation until the situation corrects itself.

DR. WR. TROST

How long would it take you to pull back after you have had an indication?

MR. W. CHALMERS

The actual indication comes before the peak reading. Our peak reading is at 0.15 ppm SO_2 and at 0.1 we do get an indication. We can then pull back, but it is a difficult thing to say how long it would take to pull back as there are quite a number of factors involved, although in a fairly serious situation all our wells are on push-button control and we can shut the well down right from the control center and back everything off its source.

DR. W.R. TROST

With your plant running in a routine way that meets specifications, then probably your biggest worry is an upset of some sort, isn't it?

MR. W. CHALMERS

This is correct.

DR. W.R. TROST

Do you want to talk a bit about what kind of environmental problem an upset might lead to?

MR. W. CHALMERS

In the matter of upsets there are quite infrequent conditions now. Most of the units at the plant are now running on a 99 per cent factor, and it is generally about every 12 to 14 months, that we take our plant down for an annual overhaul. That is a service factor which we enjoy doing. In the event of a major upset we have a number of things that we can do. One is that we can just push a button and shut the wells off at source, or we can activate emergency systems which will shut off all the incoming valves at the plant limits and prohibit any gas coming into the plant. We can also, by remote control, shut off Alberta Gas Trunk to save the sweet gas from coming back into the plant and literally blocking the plant solid; then we can dump the plant flare in an extreme emergency. These flare stacks, it should be appreciated, are our life-line so to speak in the event of a major upset, and you have 325 million cubic feet of very toxic gas coming at you. When you get that problem you will dump that to the flare pretty quickly and the gas that goes to the flare is metered all the time. You have to report all your flarings to the authorities and the requirements are that you add sufficient fuel gas to that sour gas to completely burn everything going up the stack of SO_2.

DR. W.R. TROST

So you have many provisions for upset but your final safety is to burn.

MR. W. CHALMERS

It has to be burned yes. The reason for this of course is that your scrubbing solutions get saturated with sour gas and there is just no way to clean them up unless you go to flare and burn it off until they are sweet.

DR. W.R. TROST

What is the nature of the complaints or information that citizens bring to the plant?

MR. W. CHALMERS

Generally someone will say that there is an odor coming downwind from us. There are always people out in the field--field operators. We have 50 wells and being in a 200-square-mile area they are always in radio contact so we can dispatch a field operator out into that particular area to talk to the person involved. His truck is completely equipped with life-saving equipement and also H_2S-SO_2 sensers. He can sample the area, check if there is anything and then radio his findings to the plant. Generally it is an odor coming along from different sources and different areas.

Dr. W.R. TROST

The history of these complaints. Do they show an increasing or decreasing trend?

MR. W. CHALMERS

I can't recall when we had the last odor complaint.

DR. W.R. TROST

Are you in good relations with your neighbors? Will they talk to you when you meet?

MR. W. CHALMERS

Yes.

DR. W.R. TROST

Part of the Term of Reference for these hearings is to look into the regulations and legislation to see whether they are satisfactory, or can be improved, changed, or altered. Do you want to make any coment about how you feel from an industrial point of view in the operation of your plant and how these regulations and legislation, as they noe operate or as they are projected to operate, affect you?

MR. W. CHALMERS

The regulations that we have now we can live with. We have substantial records to state that we are not damaging anything. Everything in the Balzac area or our operations is good. Our relations with the neighbors is good, and the ground-level monitor system I think is really what the environment is all about. It is at ground level that we breathe and I think this should be the governing factor. I think the intent of the projected regulations was satifactory. The only problems with them are based on 1960 technology and not 1970 technology, and we have made such rapid strides in the industry in the last two years that I think the whole situation is to be reappraised on that basis. I think that these regulations were designed for plants running at 94 to 95 per cent recovery efficiency, and I think that the people are beginning to to give up the idea that the Claus unit will go much further then that, and I think that the whole thing has to be reappraised on that basis.

I would like to qualify the statement I made to Mr. Flook earlier. You really can't generalize on sulphur plants; I didn't want to give the impression that you could generalize and that 98 per cent was the magic number that you did get up to. I think that one of the problems we have today is not so much with the plant operator but with the contractor or designer who has a standard package sulphur plant and it does not matter who goes out to build a gas plant, he comes along and sticks this thing in front of you, scaled up or scaled down between 200and 1000 tons a day. There have to be a certain number of changes in thinking of these plants as individual operations. People have to start thinking that these sulphur plants and gas plants are not individual operations, and not something you can pick off the shelf. It is something that in the future you are going to have to go out and shop for rather than accept the previous standards.

DR. W.R. TROST

I would now like to start on the summary, Mr. Chalmers, and in point two of the summary you say in a very local area adjacent to the original sulphur stock pile, sulphur dust has reduced soil fertility. By what mechanism has it reduced soil fertility?

MR. W. CHALMERS

This was just pure acidity from the sulphur. There was quite a considerable duting. The area referred to here is due east of the blocks and we have a prevailing west-north west wind. This was the particular area where we had been loading unit trains for export, and there was a fairly high volume of sulphur being loaded at that time. This actually occurred in 1970 when the first unit train moved out. They started moving from the Petrogas, were all loaded at that particular area and we were loading in the order of two or three unit trains per week just right from this one corner where the equipment was all centralized.

DR. W.R. TROST

So the sulphur was oxidized sulphate and remained as sulphur acid?

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

Is that a permanent damage or can it be.......

MR. W. CHALMERS

No. On the advice of Mr. Sibbald we are undertaking a progressive restoration program. Basically this will be cured with lime and plowed in, and steps taken to improve and correct the pH.

DR. W.R. TROST

You feel that the high incidence of thistle in that same area is another result of acidity?

MR. W. CHALMERS

I don't know. No, I think it's just been left, our area, and it just has gone to weed, really.

DR. W.R. TROST

In your plant area the prevailing wind as you said is west-northwest. Do you notice a conspicuous difference in the quality of the air related to that prevailing wind pattern?

MR. W. CHALMERS

No, we don't. We have extensive records of that particular area. We operated a company house about a mile and a half east of that particular area. The elevation of the company house is 100 feet higher then the plant site and there is no incidence of any damage in that area.

DR. W.R. TROST

How many tons of sulphur in that area are you producing?

MR. W. CHALMERS

Our plant is on the decline now and we are producing about 1500 tons per day. Our quota design is 2000 tons per day.

DR. W.R. TROST

How much sulphur dioxide are you releasing to the atmosphere?

MR. W. CHALMERS

We have two stacks. Generally each stack will emit about 20 to 25 tons per day.

DR. W.R. TROST

You are releasing from both stacks. Are they close together?

MR. W. CHALMERS

About 600 feet apart.

DR. W.R. TROST

So from the two stacks then you are releasing 40 to 50 tons per day.

MR. W. CHALMERS

Yes.

DR. W.R. TROST

Do you know over what area these gases move before they come to earth?

MR. W. CHALMERS

The stacks are designed on the basis of the Sutton-Laurie modified equasion which would indicate that the out fall should be 50,000 feet down. That is about 10 miles.

DR. W.R. TROST

Fifty thousand feet downwind--about 10 miles. With the prevailing winds do they move further? Is that taking account of the prevailing winds?

MR. W. CHALMERS

That is designed under the worst conditions that possibly could happen, 14.7 mph.

DR. W.R. TROST

If you were to calculate that in terms of your probable configuration for the direction of the wind blowing on the average, how many pounds per acre of sulphur would come down in a year?

MR. W. CHALMERS

I don't know. I have never really gone that far in getting pounds per acre.

DR. W.R. TROST

Could you get it?

MR. W. CHALMERS

Yes, we could get it and submit it to you. Just as a matter of interest, we have one monitoring station located up in Huntington Hills. This monitoring station is located up there by the Canadian Western Gas Meter Station. It was put up there before any houses exsisted. It is practically on the Sutton-Laurie fallout area. It is also on the highest terrain around the area. I think we have had one or two readings since we had that station up in operation. That would be a north-northeast wind, and actually the location was picked because both tracks are line-in-line with that metering station.

DR. W.R. TROST

Do you think it would be possible to have the answer to that question while we are still here in Calgary?

MR. W. CHALMERS

Yes, I think so.

DR. W.R. TROST

In point four in your summary you are talking about your good record of plant management, and then you say despite the attrition experience because of the other sulphur operations starting up. I assume you are referring there to what might be called staff rating. Is that right?

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

So that your loss is other's gain, is that correct?

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

How do you train your people?

MR. W. CHALMERS

It is all on-the-job training.

DR. W.R. TROST

Now is all your staff given safety and environmental protection training of some sort?

MR. W. CHALMERS

Yes, we do have very strict safety regulations and we do have weekly and monthly meetings with the shift groups who are lectured to and shown films by the Safety Supervisor in the plant. We have a full-time safety supervisor and the drills and program are dictated by the weather-inside lectures or outside when conditions are favorable. Each month we have a plant tour with the various hourly paid employees, who go around the site with the supervisor and report any malpractices or items needing attention and these are brought to the attention of the senior management.

DR. W.R. TROST

Are the workers unionized in your plant?

MR. W. CHALMERS

Yes, they are. They are under the Local of the Edmonton of the Oil Chemical and Atomic Workers Union.

DR. W.R. TROST

Does the union play any part in these training and safety precautions?

MR. W. CHALMERS

Not directly. The Union members and the Union officers in the plant are included in the lectures.

DR. W.R. TROST

Are they seeking to play a part?

MR. W. CHALMERS

Not really; they have been quite happy with our progress in safety and they have left us strictly alone.

DR. W.R. TROST

The reason I ask is because the one Union had made a submission showing an interest in the administration of these programs. What is your sulphur recovery efficiency?

MR. W. CHALMERS

We are operating under sort of a permit from the E.R.C.B. which has recognized our achievements in the field of Claus technology. We had a major public hearing in December of 1970. At that time, they gave us a three-year permit to operate which would allow us to operate at 95,96 and 97 per cent for each of the three years during our operations and research program. These recovery efficiencies had to be averaged by quarters. We had to establish 95 per cent any quarter of one year, 96 per cent in a quarter of another year and 97 per cent in the final year. This was subject to coming back in 1972 to give the Board an account of our progress during the previous 18 months. We have been very successful in meeting the Board requirements for that period of time and we are currently operating with three sulphur plants. They are each at different levels of efficiency, but our average efficiency is well up in the 96 per cent recovery efficiency; therefore we do have some plants operating in the 97 per cent plus range.

DR. W.R. TROST

Now what is the guideline set by the Board for your plant?

MR. W. CHALMERS

If the guidelines become effective we will be required to operate with

98.2 per cent recovery efficiency.

DR. W.R. TROST

You are appealing that you are not?

MR. W. CHALMERS

We are appealing, yes.

DR. W.R. TROST

You have had your hearings before the Board on this?

MR. W. CHALMERS

That is correct.

DR. W.R. TROST

It is partly relevant to our own hearings of course to look into these matters in certain ways. Do you want to elaborate any further than you have in your submission on the reasons that compel you to appeal the guideline for your company?

MR. W. CHALMERS

No. Other than that I could just reiterate my previous statement, demonstrating that we beleive the all-important thing is ground level concentration, and that we can operate 99.7 per cent of the time in any given year with a ground level concentration of 0.15 per cent with no damage; we don't see any need to go for 98 or 99 per cent recovery efficiency in a sulphur plant. We beleive that the ground level recovery is sufficient to protect the environment and the population in the area.

DR. W.R. TROST

Despite the 50 tons of sulfur that you are putting out a day.

MR. W. CHALMERS

Yes. Also that 50 tons is leaving each stack-the stack is emitting about 20 to 25 tons of sulphur, and that the gas is leaving the stacks at 65 mph. Most of the equasions that we use for the sulphur plant stacks are getting quite outdated now. They were developed a long time ago, particularly for power plants, and we are not too sure yet of their relevance to these high temperatures, high velocity stacks that we are using in Alberta. We have some peculiar meteorological conditions here that are unique, and this is an area of investigation.

DR. W.R. TROST

But you must have some other reason to oppose the guideline than just the fact that you think you are now not creating environmental effects.

MR. W. CHALMERS

Yes, there is a very significant economic reason for us to put on a trial -end process. Again we are quite different from most of the plants. We have three sulphur plants, one at 1100 tons per day and two 450 ton per day units. The two 450 tons per day units go one stack, and the 1100 tons per day unit go up its own individual stack, so we have a different situation altogether. We would be faced with more then one tail-end process. We have examined these things in depth and we would be looking at a capital investment somewhere on the low side of three or three and a half versus five or five and a half million dollars. I think the operating costs of these units are quite considerable. People are inclined to think more on capital. This is a one-shot deal you pay at once. When you are faced with half a million to three-quarters of a million dollars per year operating costs, and operate a tail-end process--we all know that operating costs are tied into cost-of-living inflation that they go on forever, and at the best can be guesstimates too in certain respects --I would hope to say that from the knowledge that we have at this time, we would not be looking at less then half a million dollars to operate a tail-end plant, and to be realistic would be operating somewhere within an operating cost of three-quarters of a million to one million dollars per year.

DR. W.R. TROST

Are you presently selling the sulphur as you produce it or are you stockpiling it?

MR. W. CHALMERS

We are a unit train plant. There are only a certain number of plants of a size sufficient to sustain a unit train movement; the qualifications are that there has to be a plant able to sustain 1500 tons per day. This keeps your unit costs down on your slating units and also makes it possible to get these trains out.

DR. W.R. TROST

You are in fact producing to demand as it were?

MR. W. CHALMERS

We are producing to demand to the producers' nominations for export and shipping direct to Vancouver. For our own domestic sulphur, then, we have to go to others to ship liquid sulphur for us in exchange for flakes that we ship to them for export.

DR. W.R. TROST

One of the problems in converting the plant to improve the efficiency of sulphur recovery is the difference between the differential cost and the different concepts of looking at the increased cost of increasing sulphur as against the overall cost of the overall sulphur. I gather from what you say that the increased cost to get this increased sulphur is not apt to be too profitable.

MR. W. CHALMERS

No, it definitely isn't profitable. I have had all sorts of figures, from $75 up to $90 per ton, to get that incremental sulphur from the tail-end process.

DR. W.R. TROST

What is it is looked at from the other point of view? From the overall cost and the overall sulphur recovery with this improved installation? You are now recovering sulphur at 96 per cent, and you may have to go by the guideline, which you are appealing, up to 98.2 per cent, doesn't match the increased revenue for the extra 2.2 per cent as against the total recoveries from that 98.2 per cent?

MR. W. CHALMERS

I think that you mean averaging the costs, really. It is a different viewpoint when you start averaging the costs. I personally beleive that a sulphur plant can be taken up to 98 per cent recovery efficiency very shortly without any tail-end cost, and without these increases in operating costs that we are talking about, and this is where I beleive our future is.

DR. W.R. TROST

Are you using Claus technology?

MR. W. CHALMERS

We are using the Claus technology as we know it today, with certain improvements that we have developed ourselves.

DR. W.R. TROST

Are you prepared to elaborate on that now?

MR. W. CHALMERS

Not at this time. I would rather elaborate on that at a later date.

DR. W.R. TROST

How much later? It would be interesting to us to have an elaboration.

MR. W. CHALMERS

This is to be subject to company approval, at least at this date. I do now know that a Claus plant can be taken at 98 per cent because I have been there. The only problem is that we don't know how to stay there at this point in time.

DR. W.R. TROST

I would just like to get your views on one further point, which seems to be an important element of your recommendations. It is in the first recommendation, that ambient air quality standards be the regulating factor in sulphur plant operations rather than an arbitrary sulphur recovery efficiency or than point source emmision limitation. Right now you are working with arbitrary sulphur recovery efficiency guidelines, are you not? So your recommendation is for the removal of that system?

MR. W. CHALMERS

Yes. This specifically means the guidelines. This is an arbitrary thing. It was 98 or 99 per cent recovery efficiency--we had to get up there. This is what I mean by the arbitrary sulphur recovery efficiency, and by point source emission limitation I mean the emission from the stack.

DR. W. R. TROST

Why do you oppose that? It seems to me that your recommendation is opposing that. It doesn't exsist now, in any event.

MR. W. CHALMERS

No, it does not exsist as such, but what we are recommending is that the ambient air quality standards the regulating factor. We do have ambient air quality standards now in Alberta which are satisfactory for the purpose. If the plants are capable of meeting these ambient air standards we don't need any 98 or 99 per cent recovery efficiency or point source submission limitation, provided of course that the area concern--the environment--is suitably monitored to guarantee that no pollutants are causing any damage.

DR. W.R. TROST

Have you any other reason to recommend against point source? That would really be emission control in the incinerator stack for example, or in the flare stack. Have you any other reason to recommend against controls at those effluent points? It is not a cost matter of either operating or capital cost? Your opposition to the sulphur recovery efficiency approach is again not one in principle but just merely that it is not necessary. Is that right?

MR. W. CHALMERS

That is correct.

MR. W. CHALMERS

I think I would just like to restate that the brief summary I gave this morning was really a very small condensation of the document we submitted to the Environment Conservation Authority. On the question of the area where the thistles were predominant, this has lain fallow two years, so I don't think there is any significance there. The farmer just leases that land and it is entirely at his option whether he does anything with it or not. As a matter of public records, when we built that plant at Balzac it was not just a decision of Better Gas or the operator, Canadian Occidental to go ahead and stick a plant in there. I think it's important to recognize that before you build any plant in Alberta you have to go through certain procedures and the Petrogas operation is no exception. We had planning authority from the district planning commission, the Rocky View Municipal District Planning Commission, the Alberta Department of Health, the Rocky View Municipal Department of Public Health, the Alberta Department of Labor Boilers and Pressure Vessels Branch, Alberta Department of Labor. Electrical Protection Branch, the Provincial Department of Health, the Provincial Department of Mines and Minerals. Pipelines Division, the Federal Pipelines Division, the Oil and Gas Conservation Board of that time, the Federal Department of Transport, the Federal Department of Customs and Exise, and the Calgary City Council. This is quite a formidable list; we weren't on our own. The other time I have here is a submission we made to the Energy Resources Conservation Board recently. At the time we made this we had no complainants from industry, the public sector or the government. They accepted our request as presented. They haven't ruled on it. A copy of this document was also lodged with the Environment Conservation Authority. I think its quite pertinent to read out some of these items that we had in this submission. With respect to sulphur recovery efficiency, Petrogas is required to meet not less than a 96 percent level averaged during each calendar quarter until December 31, 1973. Thereafter, Petrogas will be required to meet an efficiency level in the range of 97 to 99 per cent as determined by the Board, following receipt of a submission by June 30, 1972. With respect to stack emissions of sulphur dioxide, Petrogas had had from November 1, 1971 a number of available options; with the operation of a seven station monitoring system, SO_2 emissions must not exceed 200 long tons per day. Two other options deal with the conditions where Petrogas operates less than seven acceptable monitor stations, or does not use ground level monitoring control at all. In these latter two cases, the maximum permitted SO_2 emission level is 122 long tons per day. I mentioned earlier that we were currently emitting something in the order of 40 or 50 tons of sulphur per day. 50 or 60 percent of our actual allowed emission level. With respect to ground level monitoring control, Petrogas must continuously record atmospheric SO_2 concentrations, continuously transmit SO_2 concentration data to the plant, and initiate corrective action as soon as an SO_2 concentration exceeding 0.15 part per million per fifteen minutes is detected at one or more stations, unless the wind speed and direction clearly indicate that the source of SO_2 is outside Petrogas jurisdiction. On November 1, 1971 the Board released its minimum sulphur recovery efficiency guidelines in an informational letter, No. IL71-29. For the Petrogas Plant with the approved inlet rate of 1925 long tons per day of sulphur, 51.3 million cubic feet per day of H_2S or its present sulphur inlet rate of 1500 long tons per day, the guidelines indicate that the recovery efficiency will be in the range of 98 to 99 per cent. It is Petrogas' understanding that for an existing processing plant, the guidelines should be met wherever practicable by December 31, 1974, but that grading to meet the guidelines may not be justified for certain older plants, and that this understanding is consistent with the terms of our approval, No. 1477. Petrogas Processing Limited hereby makes application for authority to operate under the following conditions: the sulphur recovery efficiency from January 1, 1974 shall be not less than 97 per cent averaged over each quarter; the terms of approval, Nos. 1477 and 1477 A, other than various clauses which refer to either the required recovery efficiency or are out of date shall be continued indefinitely. Petrogas submits that it has valid and substantial reasons for this application. The reasons are summarized and supported by detailed material in the balance of the application. I won't go into that because it is a very extensive document, but I will read the highlights of it to you. The Petrogas Plant has been in operation almost eleven years, having been placed on stream in 1961. The plant is therefore an older plant, and as such would require substantial upgrading to meet a 98 per cent or better sulphur recovery efficiency. Petrogas is planning to invest $6.4 million dollars of additional funds over the next twenty years to upgrade the efficiency of the Claus units, and it will achieve a recovery efficiency that will result in long-term maintenance of ambient air quality standards at an acceptable and reasonable cost leve. Substantially higher costs would be necessary to achieve any recovery efficiency materially above 97 per cent, subject to further advances in Claus process efficiency, costs that in Petrogas' view are unreasonable and unacceptable and that will likely never be economically justifiable. The provincial ambient air quality standards have been met better than 99.96 per cent of the time. Our research on the fundamental Claus process has been particularly rewarding during very recent years, with respect to improvement in sulphur recovery efficiencies, and it is in this direction that we should continue to look and expect further improvements with time, especially for the immediate future. The field gas production is projected to commence deliverability to decline below the requested inlet capacity of 45.3 million cubic feet per day of hydrogen sulphide gas in 1975, thus progressively reducing the daily amount of gas available for processing and the level of SO_2 equivalent emissions compared to present levels. The atmospheric corrosion rate is determined at stations both close to the plant; at Alberta reference stations it is shown that the most severe corrosion rates occurring at most of the plants are only slightly greater than the rates recorded at the background stations located east of Strathmore, and are approximately the same as at reference stations in Calgary and the Lacombe Agricultural Experimental Station. The requested 97 per cent sulphur recovery efficiency which we requested to become effective on January 1, 1974 is one year earlier than the date specified by the Energy Resources Conservation Board guidelines. The sulphur dioxide emissions at that time would be only 66 per cent of those permitted under the current terms of approval. In a near monitoring survey report dated June 23, 1972, for the period March 29 to May 24, 1972 the Department of the Environment stated, "A relatively high frequency of SO_2 readings was monitored. However, the monitoring results indicate atmospheric SO_2 and H_2S levels considerably below the Alberta ambient air quality standards. This reflects responsible plant operation and it is our sincere hope that this kind of commendable operation will be maintained". That's as far as I wish to go on that particular matter, Mr. Chairman. I do have some figures that you requested this morning. They have to be just assumed to be a very ball park figure on the basis of the following. We discussed from the stack the following: when the gas is being emitted is 65 mph and the winds that we get around Alberta have to be a sort of dubious thing we estimate, again I would state this is ball park, we would have a rectangular area about 20 or 24 miles to catch this fallout. This disbursal at our current emission level would amount to about 10 pounds per acre per year. Now this is quite possibly not sulphur. There is some complex chemistry going on at the level that this gas is emitted from the stacks, and there are some thoughts that the SO_2 becomes SO_3 and then ultimately will fall out on the ground as $CaSO_4$, calcium sulphate; this is actually the ground level consideration, possibly more than SO_2. I'm not prepared to be examined on this yet, as I still wish to do some additional work on it, but this is the basic simple chemistry. It happens up there; it can get a little more complex.

DR. W.R. TROST

The ten pounds per acre per year is that calculated in terms of SO_2 emissions or the sulphur in the SO_2?

MR. W. CHALMERS

That is calculated on SO_2 ground level; sell, it can be SO_2 ground level, we've calculated that out as calcium sulphate. We're assuming it is converted into calcium sulphate.

DR. W.R. TROST

But the figures that you are using are from the .....

MR. W. CHALMERS

SO_2 emitted from the stack.

DR. W.R. TROST

SO_2 emitted from the stack. Right.

MR. W. CHALMERS

That's the conclusion of my testimony Mr. Chairman.

TOWN OF OKOTOKS
OFFICE OF MUNICIPAL SECRETARY

PHONE 683-4288
P.O. BOX 419

October 10, 1972.

Environment Conservation Authority,
9912 - 107 Street,
Edmonton, Alberta.

Dear Sirs;

On behalf of the Town of Okotoks, we are submitting herewith, a short brief regarding our thinking with respect to the operations of the Texas Gulf Sulphur Company Inc. plant, situated in the Municipal District of Foothills #31, and adjacent to the Town of Okotoks.

It is the belief of the Town Council that the operations of this plant are highly efficient and with the modifications to the plant that have been carried out through the years, we would say that the operations of this company are highly commendable in every respect.

While we certainly are far from being experts in the operations of sulphur extraction gas plants, we have observed no detrimental effects on either humans or animals. The company and its officials have proven themselves to be good corporate citizens and have cooperated with the Town in many matters of mutual concern. Should it be found necessary to make modifications in the operations of this plant, we would feel that these would be minor ones and would be quite confident that Texas Gulf Sulphur Company Inc. would cooperate with the governing authority in every way.

We have noted in news items, considerable criticism from various areas in the province regarding the oeprations of this type of plant, but insofar as Okotoks and area is concerned, we do not feel this to be the case in the Okotoks locality.

Yours very truly,

P.B. Milligan,
Mayor.

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

Mr. Milligan, I wonder if you could tell us whether, since the plant became operable in the area, the Council had any information or complaints brought to it by any of the citizens residing in the Town with respect to the operation of the plant?

MR. P.B. MILLIGAN

No.

MR. W.A. FLOOK

Mr. Milligan, how far from the Town of Okotoks is the plant?

MR. P.B. MILLIGAN

It's on the border to the town limits.

MR. W.A. FLOOK

Right on the border of the town limits?

MR. P.B. MILLIGAN

Yes.

MR. W.A. FLOOK

And in what direction with regard to the wind?

MR. P.B. MILLIGAN

Straight east.

MR. W.A. FLOOK

It is east of the Town? In other words, downwind?

MR. P.B. MILLIGAN

That's right.

MR. W.A. FLOOK

So that, really, the only time that you would expect to be aware of the presence of the plant would be in cases of a southeast wind, or an easterly wind?

MR. P.B. MILLIGAN

Yes, that's right.

MR. W.A. FLOOK

And this doesn't happen very often?

MR. P.B. MILLIGAN

Not too often, no.

MR. W.A. FLOOK

You think that might be one reason that its presence has so little effect on you, that it was indeed well located with respect to the Town?

MR. P.B. MILLIGAN

Partly so, but I don't think there is that much detrimental effect from it, because we have people that live adjacent to the plant on the southeast of the area and they don't seem to feel it's a very big concern.

MR. W.A. FLOOK

Thank you very much.

DR. W.R. TROST

Mr. Mayor, you indicated that there is a good working relationship between the Town, the governing authority and the Company. Is there any formal exchange of views between the two? Is there any regular relationship between the Town and the Company?

MR. P.B. MILLIGAN

No, I wouldn't say there is any regulat relationship; if there are any problems arising in either case, they are dealt with as they arise.

DR. W.R. TROST

Right. You indicate that you were aware of considerable criticism from various areas within the province regarding the operations of this type of plant in other parts of the province. In some of those cases there had been research activities by the companies into environmental effects, and these were of interest to the citizens that were involved, but you are making it quite clear both that there is no concern of this sort in the Okotoks region and that the relationships between the Town and the Company are quite good.

MR. P.B. MILLIGAN

That's right.

DR. W.R. TROST

Have you any view about what might be the case in the other communities where complaints have been lodged?

MR. P.B. MILLIGAN

No, I wouldn't

CANADIAN PETROLEUM ASSOCIATION

Submission to the

ENVIRONMENT CONSERVATION AUTHORITY

The Environmental Effects Of the Operation of Sulphur Extraction Gas Plants in Alberta

Presented by: J. E. Baugh

September 29, 1972

The Canadian Petroleum Association acknowledges with thanks the contributions made to the compilation of this report to the following consultants:

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Dr. R. M. Holmes
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Mr. J. Lukacs

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R. C. Egglestone	Sun Oil Co.
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A. Yahya	Pacific Petroleums Ltd.

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CANADIAN PETROLEUM ASSOCIATION

BRIEF TO

ENVIRONMENT CONSERVATION AUTHORITY

Introduction & Policy Statement

The series of public hearings on the Environmental Effects of the Operation of Sulphur Extraction Gas Plants in Alberta was announced by the chairman of the Environment Conservation Authority - Dr. W. R. Trost on July 14, 1972. The prospectus for public hearings, which was included in the announcement stated in part:

> The Authority hopes that some briefs will be able to provide first hand or specialized information on particular aspects of the subject about which general knowledge is deficient, or where misconceptions might be considered to exist.
>
> Factual information or data on cause/effect relationships connected with the operation of gas plants and their transmission lines, would be of particular interest.

It is in response to these two general requests that the members of the Canadian Petroleum Association have directed the major portion of their brief.

More specifically, our brief considers each of the sixteen points, which the two consultants for the Environment Conservation Authority, Dr. William MacDonald and Dr. Roger Klemm, accepted as their terms of reference, in preparing their "resume of the sour gas industry and its attendant impact upon the province of Alberta". The authors (MacDonald and Klemn) have admirably accomplished their stated purpose viz. - "to outline the present situation in Alberta concerning sulphur extraction plants and to describe the present technology employed in sulphur extraction".

Certainly, in light of the short two and one-half months allotted the authors to gather the information on such a broad subject they have performed a creditable job.

While one may well question, in an environmental effects investigation, the relevancy of such matters as:

(i) foreign ownerships of both plants' operating and construction companies, or

(ii) the few personnel directly employed in the highly automated process industry versus the older and highly labor intensive manufacturing industries,

the CPA Committee has addressed itself to the Environmental and Technical aspects of the Status Report.

The Canadian Petroleum Association represents some 191 oil and gas exploration and producing companies in the province of Alberta.

The association's Environmental Conservation Policy clearly states our desire to participate in public hearings such as this, in order that we may assist the Environment Conservation Authority as they enquire into all affects on the environment of the operation of sulphur extraction plants and review all legislation pertaining thereto.

ENVIRONMENTAL CONSERVATION

Statement of Policy

by

CANADIAN PETROLEUM ASSOCIATION

1. The Canadian Petroleum Association fully supports and encourages efforts to prevent pollution and conserve Canada's environmental resources.

2. The Association believes the responsibility for protecting our environmental resources should be shared by individual citizens, business and industry and municipal, provincial and federal governments.

3. The Association supports the efforts of Federal and Provincial governments to continually reappraise standards for conservation of air, water and soil resources. The Association believes that the federal government can provide general guidelines and minimum standards, but that the provincial governments should establish environmental regulations and standards which are applicable to specific local circumstances within that provincial government's jurisdiction.

4. The Association endorses intensive, cooperative government, industry and university study of environmental conservation. The Association believes that thorough study of all scientific, economic and social factors is the only sound and responsible basis for environmental regulations and standards.

5. The Association pledges continued cooperation with all levels of government to seek practical standards to assure effective and economic utilization and conservation of our environmental resources. The Association welcomes any opportunity to review proposed legislation and prepare constructive comments for consideration by governmental authorities.

6. The Association is pleased to act on behalf of the Canadian exploration, development, production and pipeline segments of the petroleum industry in support of this policy.

Approved by the Board of Governors, January 20, 1970.

SUMMARY

In the preparation of this brief the Canadian Petroleum Association engaged the services of five consultants to study and report on the environmental impact of Sulphur Recovery Plants in the province of Alberta. The results of the consultant's investigations, combined with those of an "in-house" study by a special task force of the CPA's Environmental Conservation Committee, constitute our submission.

The initial section of the report considers briefly the "Industry", in terms of its history and economic benefits to the province, and somewhat more extensively the industrial practices as they relate to the welfare of operating personnel and to the protection of the environment beyond the plant boundaries.

The brief next considers the consultant's reports, which include extensive literature searches as well as personal investigations of the effects of sulphur dioxide on vegetation, animal life and human welfare. These data were subsequently used to assess Air Quality Standards and the Legislation pertaining thereto in the ensuing sections of the brief. This assessment indicated that the legislation governing the Sulphur Recovery Industry is presently adequate to protect the environment.

An intensive evaluation of the methods employed in stack design for various conditions illustrated that the present methods constitute a sound design basis.

The effectiveness of the incinerator stack is continuously monitored to ensure that the established air quality stand-

ards are being achieved. Outlined in the brief are several promising new techniques for rapid assessment of environmental reaction, along with methods to assist in differentiating between natural and induced vegetation stresses.

Finally, the brief presents some indication of the extensive research programs both within the industry and by industry sponsored research groups to further technological advances.

CONCLUSIONS

1. Natural gas processing plants with sulphur extraction facilities are a vital segment of the primary resource industry of Alberta. 62 such plants exist in the province and it is estimated that the investment for their construction totals over $600 million. These plants are responsible for an annual direct operating monetary flow of about $50 MM for payroll, supplies, municipal taxes, etc. In addition to their provincial impact, such plants are also important on the national scene. They provide other industries with reliable and economic supplies of fuel and petroleum products, and they purchase large quantities of manufactured products of all types.

2. The industry maintains up-to-date awareness of the latest technology as it concerns the conservation of the environment, and will continue to apply this technology to plant operations.

3. The sulphur industry is operating under strict regulations and supervision by both sulphur plant operators and the government. Emission monitoring and control procedures are effective in assuring satisfactory ground level concentrations.

4. The present Alberta Ambient Air Quality Standards with respect to sulphur dioxide and hydrogen sulphide are comparable to the national, and most international standards, which are designed to protect vegetation, animal life and human well-being.

5. Present methods of calculating ground level concentration of SO_2 from sulphur stack emissions are conservative and the record shows them to be adequate for equipment design purposes.

6. The safety performance records established in this potentially hazardous industry illustrates the results of careful design coupled with responsible operating practices.

RECOMMENDATIONS

1. The Canadian Petroleum Association recommends retention of the present Alberta Ambient Air Quality Standards for SO_2 and H_2S.

2. The Department of the Environment, in conjunction with industry, should be responsible for developing Ambient Air Quality Standards in accordance with scientifically established criteria. The Energy Resources Conservation Board should be responsible for the enforcement of air quality within these standards for the industry without resorting to additional restrictive standards.

3. Measured ground level concentrations of sulphur compounds should be the sole consideration in limiting emissions of waste gases. Air Quality Standards should be maintained through ambient air monitoring and not through restrictions on the concentration of sulphur dioxide in the stack or through the specification of sulphur recovery efficiencies.

4. Present methods employed by the Energy Resources Conservation Board for predicting ground level concentrations of SO_2 for specific stack conditions are adequate for relatively flat terrain and normal meteorological conditions and should be retained. More complex analyses of ground level concentration is recommended where unique topographical or meteorological features exist.

I THE INDUSTRY

- A. History
- B. Future Trends
- C. Economics
  - 1. Plant Economics
  - 2. Economic Benefits to Alberta
- D. Industry Safe Operating Practises
  - 1. General
  - 2. Drilling
  - 3. Producing Operations
  - 4. Pipelines
  - 5. Plant Operations
    - a. General
    - b. Explosions and Fire
    - c. H_2S Inhalation
    - d. Chemical Burns
    - e. Noise
    - f. H_2S and SO_2
    - g. COS and CS_2
    - h. Electrical
    - i. Other
- E. Plant Upsets
- F. Sulphur Storage and Transportation

I THE INDUSTRY

A. HISTORY

Alberta's first gas plant (with sour gas removal facilities) was constructed in Turner Valley in 1933 for the conservation of solution gas. In 1951 the Jumping Pound plant went on line and became the first plant to produce elemental sulphur in the province. Since that time sour gas production has increased to the present volume where gas from plants of this type comprises more than one-half of Alberta's natural gas production.

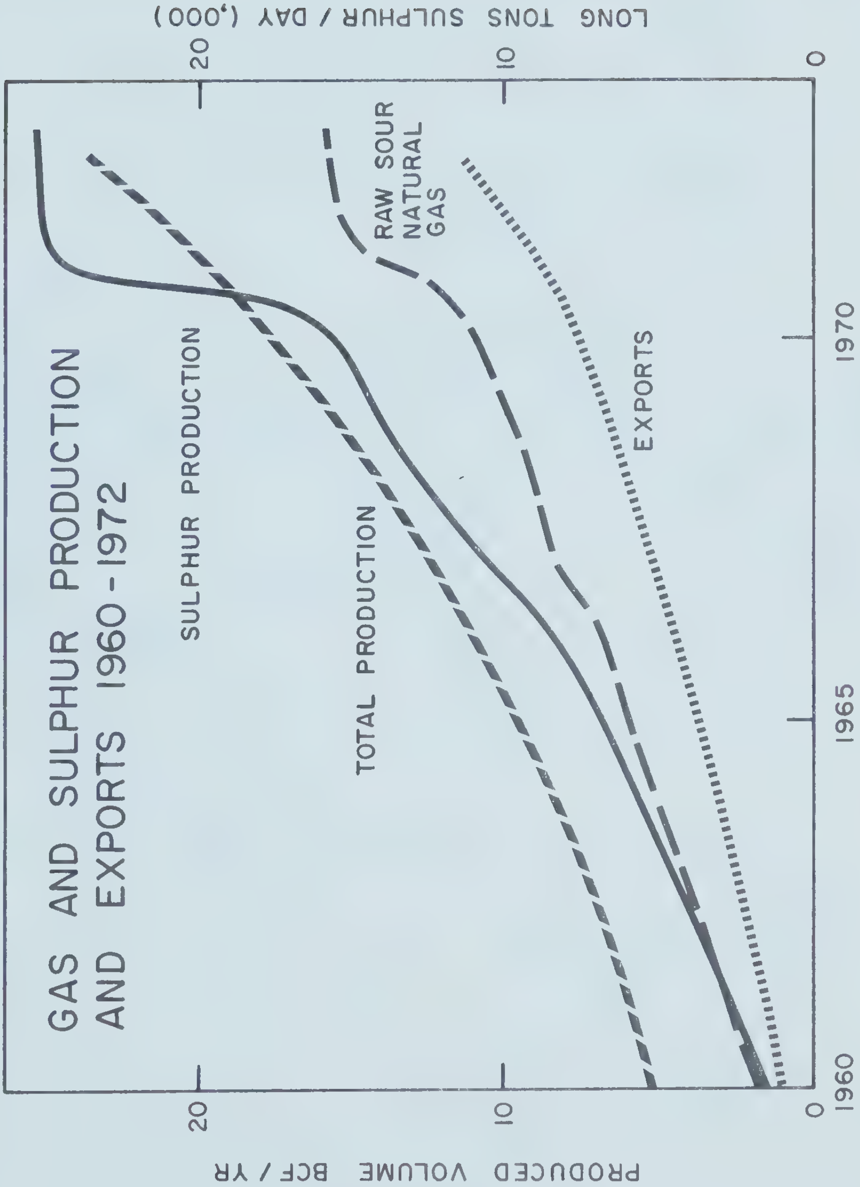
Whether measured by provincial, national or world standards, our gas industry is big and sour gas processing is a significant portion of this industry. In 1970 Alberta produced more natural gas than any American State with the exception of Louisiana and Texas. Total 1971 Canadian production was 5,270 MMCFD of natural gas, of which Alberta produced 4,400 MMCFD or 83%. More than 55% of Alberta's gas production was from plants processing sour gas.

Figure I-1 through I-5 and Table I-1 show the growth and uses of Alberta and Canadian natural gas.

B. FUTURE TRENDS

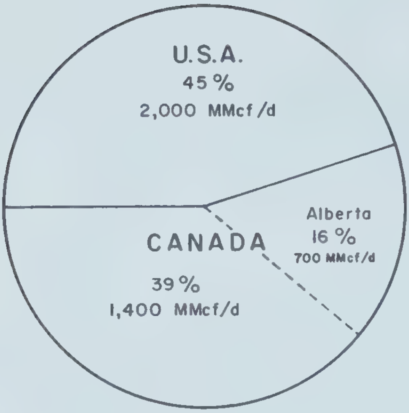
It is readily apparent that the reserves of petroleum, natural gas and sulphur in the province of Alberta are limited and finite. The ERCB has estimated that the marketable reserves of sulphur in sour natural gas will increase from the present 180 MMLT to about 240 MMLT in 1980, see Figure I-6. During this period sulphur production is expected to increase from 4.5 MMLT/year to about 10 MMLT/year.

Based on the current average sulphur recovery efficiency of 95%+, sulphur emissions in Alberta were 600 LTD. (.22 MMLT/



ADAPTED FROM "OILWEEK", Vol. 22, No. 49, Jan. 24, 1972, Page 41

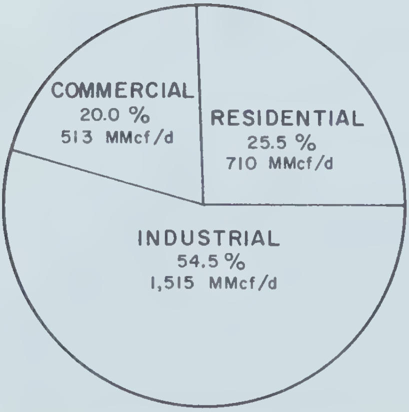
Figure I - I



Total Gas Production 4400 MMcf/d

DISPOSITION OF ALBERTA SALES GAS
1971

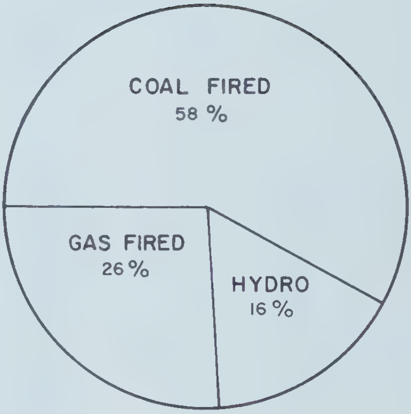
Figure 1 - 2



Total 2,800 MMcf/d

TOTAL CANADIAN GAS CONSUMPTION
1971

Figure 1 - 3



10,500 megawatt hours

ALBERTA POWER GENERATION
1971

Figure 1 - 4

1970 ALBERTA SULPHUR EXPORTS – '000 LONG TONS

Sulphur shipments from Alberta to:

Other parts of Canada	375
Outside Canada	2530

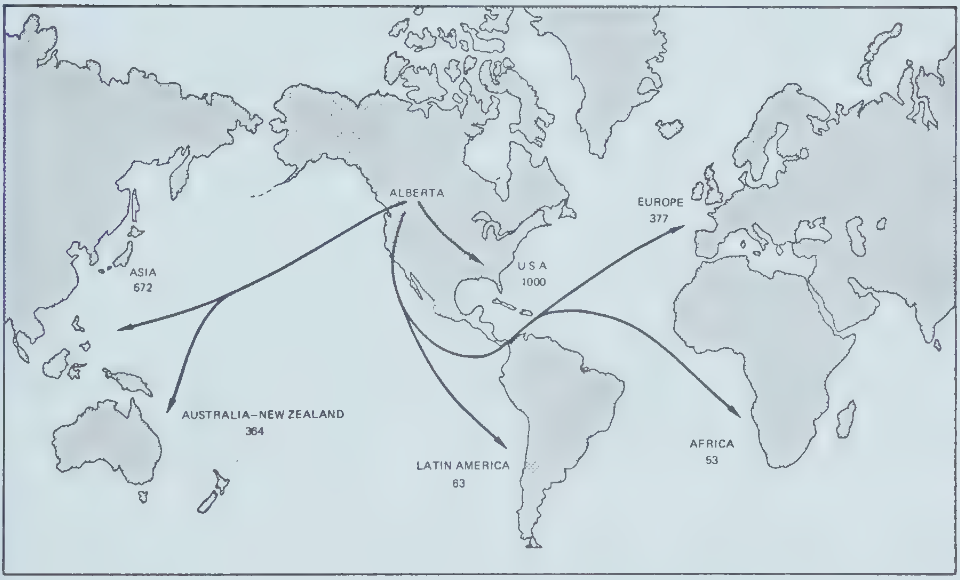


Figure I - 5

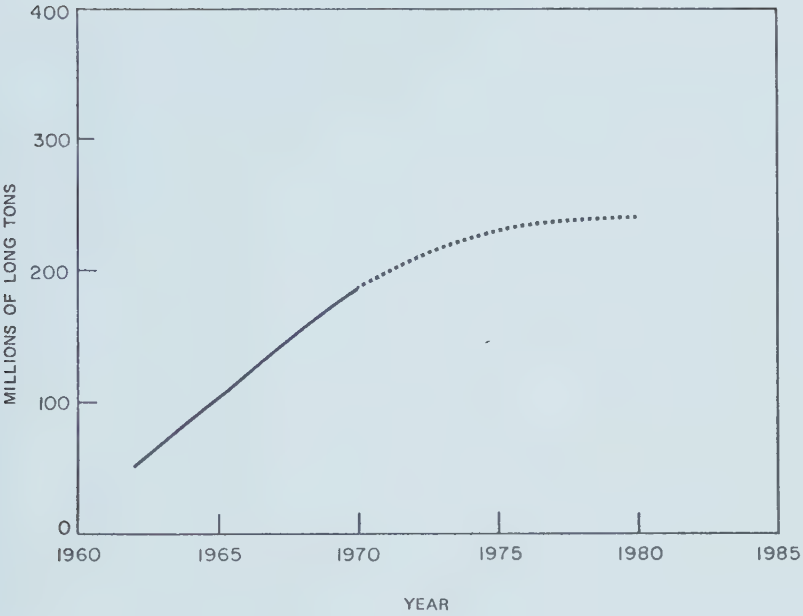
GAS PLANT CAPACITIES (1956 - 1971)

YEAR-END	RAW GAS GAS MMCF/D	RESIDUE GAS MMCF/D	PENTANES PLUS B/D	PROPANE B/D	BUTANE B/D	SULPHUR LONG TONS/DAY
1971	13,670	11,560	260,100	118,400	72,500	24,750
1970	10,722	9,490	170,823	90,240	52,319	15,256
1969	10,050	8,911	161,747	80,510	47,169	14,330
1968	8,800	7,700	144,300	73,200	43,500	12,170
1967	8,360	7,360	127,500	58,300	39,300	10,600
1966	6,600	5,500	121,000	52,200	33,800	8,135
1965	6,100	5,200	112,000	42,000	30,600	7,100
1960	1,900	1,700	24,500	10,100	7,700	1,800
1956	450	300	5,700	4,300	3,200	127

("OILWEEK" Jan. 24, 1972, Page 42)

Table I

ALBERTA SULPHUR RESERVES



Source: Alberta Energy Resources
Conservation Board.

Figure I - 6

year) during 1971. This is equivalent to 3 lbs/acre when distributed over the province. Sulphur distribution at this rate is insufficient for arable areas to offset sulphur lost from the soil by removal of crops.

Projected sulphur emissions in Canada for 1970, 1975 and 1980 are detailed in Table I-2. Presently sulphur emissions from sour gas plants constitute about 6% of the total Canadian emission of sulphur. Table I-3 lists world-wide emissions of sulphur dioxide according to source while Figure I-7 illustrates comparative sources of SO_2 in the U.S.A. The sour gas industry is included under the section marked "other". Figure I-8 shows the historical phases of sulphur production and Figure I-9 demonstrates recovered sulphur production from 1950 to 1971 in Canada, U.S.A. and France.

Exploration for new gas reserves in areas prone to sour gas (particularly in deep horizons and in the foothills area) is being inhibited by the poor rate of return that can be anticipated by any development follow-up. Development of reserves of sour gas may be restricted because of the considerable investment required to produce pipeline gas and low priced sulphur from such reserves.

Furthermore recent regulatory changes by the Energy Resources Conservation Board on plant sulphur recovery efficiency will increase sulphur plant costs very signficantly and delay the day of development of additional gas reserves. Tables I-4 and I-5 briefly detail the economics of two existing field facilities and includes the probable investments required to meet ERCB sulphur recovery efficiency levels.

The Harmattan Leduc D-3 plant produces 7 MMCFD of sales gas and 480 LTD of sulphur from field gas containing 53% H_2S. Presently this plant is operating at a loss of approximately

$90,000/year. Addition of tail gas cleanup to recover 98% of the sulphur will cost approximately $1.2 MM and will increase the operating losses to $210,000/year.

The East Crossfield Plant processes gas from the D-1 formation and produces 55 MMCFD of sales gas and 1570 LTD of sulphur. The plant has been in operation for more than four years and is still paying out the owner's original investment.

CANADIAN SULPUR EMISSIONS AND RECOVERY

(millions of long tons)

Source	1970			1975			1980		
	Total	Recov'd.	% Recov'd.	Total	Recov'd.	% Recov'd.	Total	Recov'd.	% Recov'd.
Metallurgical processes[a]	3.32	0.84	25	4.43	3.01	68	5.22	4.72	90
Coal Combustion[a]									
Electric Utilities	0.21	0	0	0.33	0	0	0.52	0	0
Other	0.26	0	0	0.20	0	0	0.19	0	0
Sub-total	0.47	0	0	0.53	0	0	0.71	0	0
Oil Processing & Combustion[a]									
Heavy fuel oil	0.44)	0.10)	17	0.59	0.35	58	0.82	0.59	73
Refining & other products	0.16)	)		0.21	0.04	20	0.26	0.06	25
Sub-total	0.60	0.10	17	0.80	0.39	48	1.08	0.65	61
Sour gas processing	0.24[b]	0	0	0.33	0	0	0.30	0	0
Tar sands processing	0.07[b]	0	0	0.07	0	0	0.07	0	0
Other[a]	0.03	0	0	0.03	0	0	0.04	0	0
Grand Total	4.83	0.94	19	6.20	3.40	55	7.42	5.38	73

Sources:
a) Dept. of Industry, Trade & Commerce Ottawa.
b) Alberta Energy Resources Conservation Board.

Table I-2

WORLD-WIDE ANNUAL EMISSIONS OF SULPHUR DIOXIDE

(as calc'd. for 1965)

	SO_2 Emission	(Calc'd. as S)
Source	million long tons	% of total
Coal*	45.3	70.
Petroleum Combustion		
Gasoline	0.16	0.25
Kerosene	0.11	0.17
Distillate	0.90	1.4
Residual	9.05	13.9
Petroleum Refining	2.53	3.9
Smelting**		
Copper	5.8	8.9
Lead	0.67	1.0
Zinc	0.59	0.9
Total	65.1	100.

*Includes lignite.
**Excludes nickel smelting (figures not available).

Calc'd. from:
E. Robinson & E.C. Robbins,
Stanford Research Institute (1)

Table I - 3

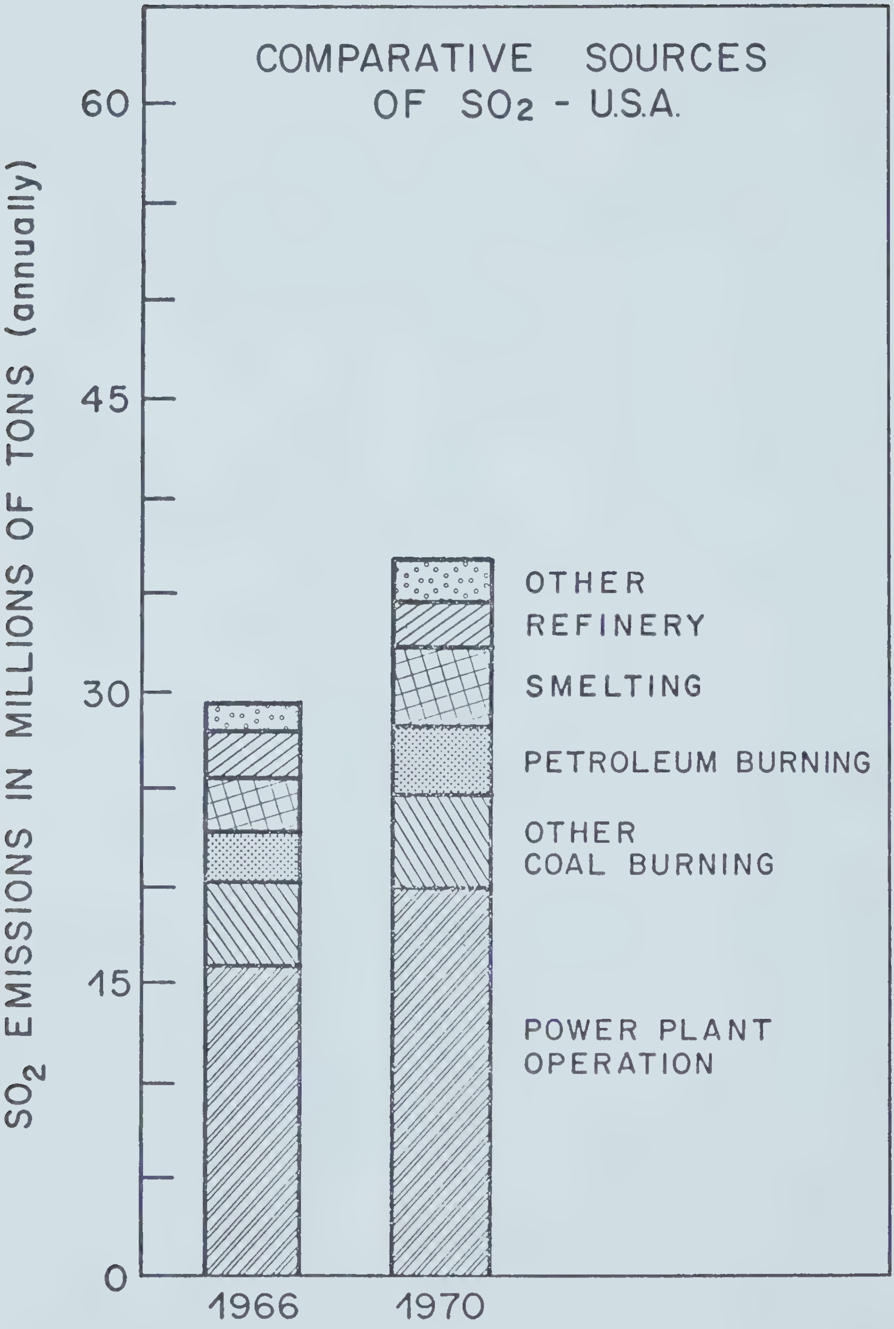

COMPARATIVE SOURCES OF SO2 - U.S.A.
SO2 EMISSIONS IN MILLIONS OF TONS (annually)
60
45
30
15
0
1966
1970
OTHER
REFINERY
SMELTING
PETROLEUM BURNING
OTHER COAL BURNING
POWER PLANT OPERATION

Figure 1

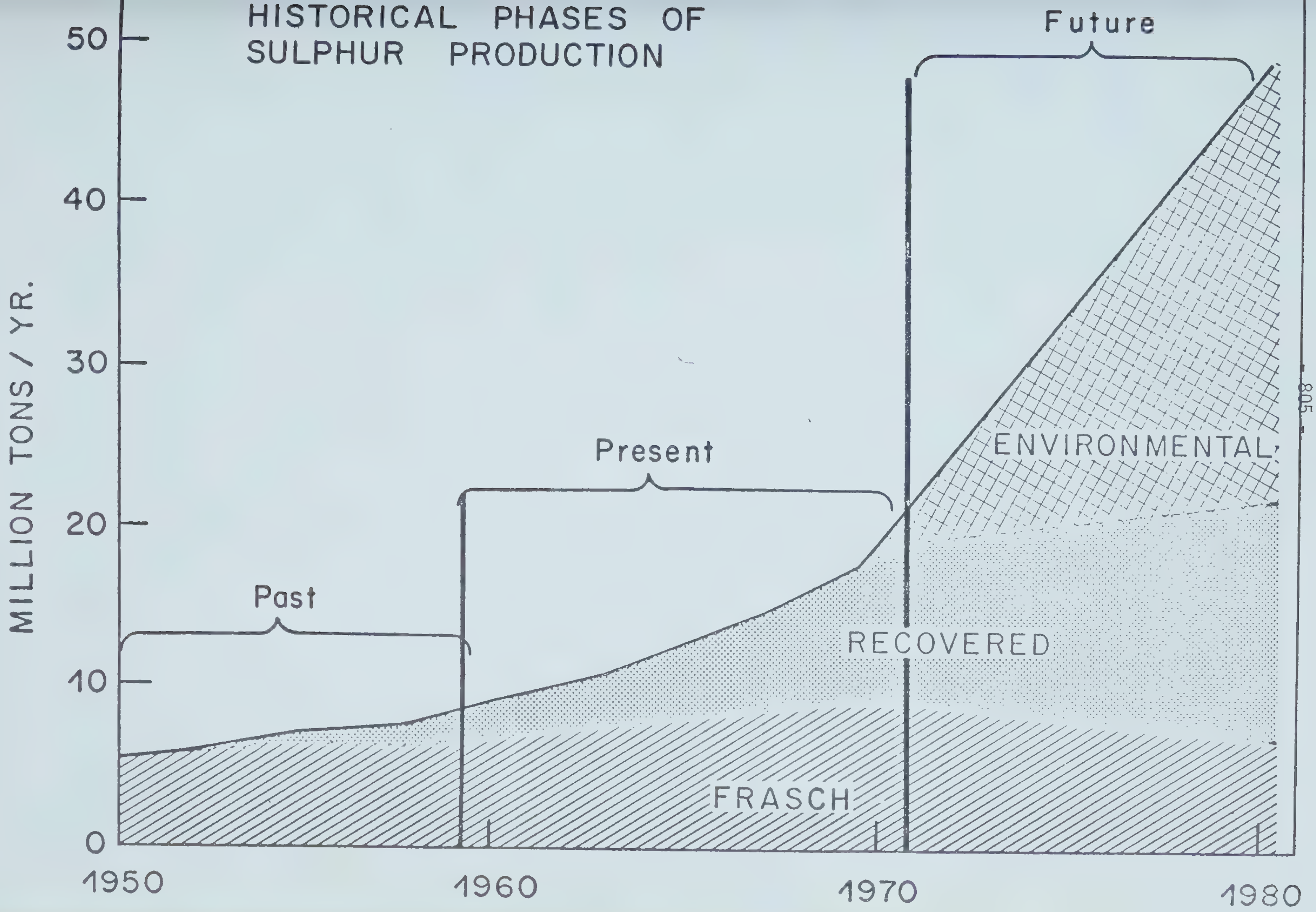

HISTORICAL PHASES OF SULPHUR PRODUCTION
MILLION TONS / YR.
50
40
30
20
10
0
1950
1960
1970
1980
Past
Present
Future
ENVIRONMENTAL
RECOVERED
FRASCH

Figure I - 8

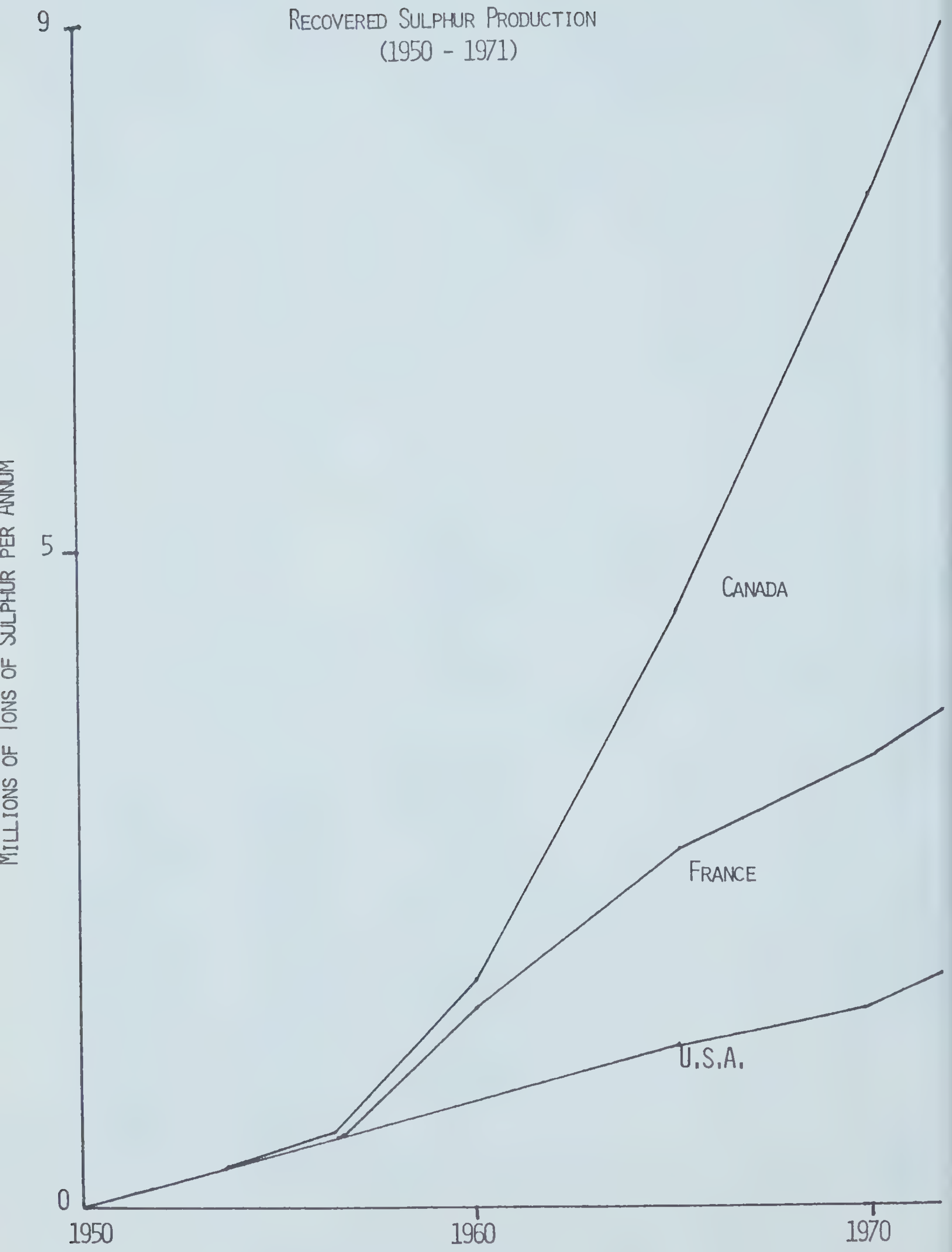

RECOVERED SULPHUR PRODUCTION
(1950 - 1971)

Figure I-

TABLE I-4

Harmattan Leduc D-3 Field and Gas Processing Plant Economics

Initial Investment Includes development, drilling, lease aquisition costs, gas gathering systems, wellsites, gas plant and sulphur plant.)		$12.8 MM
Tail Gas Cleanup (projected)		1.2 MM
TOTAL INVESTMENT		$14.0 MM
Revenues to December 1970	$23 MM	
Operating Costs to December 1970	7 MM	
NET REVENUES	16 MM	
Return after payout of investments		2 MM
Present Income	1.4 MM	
Present Operating Costs	1.5 MM	
Annual Loss	90,000	
Projected Tail Gas Plant (Annual Operations)	120,000	

From Application #6188 to the ERCB

TABLE I-5

East Crossfield D-1 Gas Processing Plant Economics

Development drilling		$8.5 MM
Dry Hole Cost (Industry average)		1.0 MM
Lease Aquisition		2.5
Gas Gathering System & wellsite		5.0
Gas Processing Plant		14.0
Sulphur Plant		8.0
Total Development		$ 39.0 MM
Tail Gas Cleanup (projected)		3.5 MM
Projected Total		$ 42.5 MM
Net Investment recovered by December 1971		$ 31.5 MM
Annual Revenue (1971) before Tax and Royalties	$5.0 MM	
Annual Operating Costs (1971)	2.3 MM	
Annual Operating Cost Tail End Plant (projected)	0.8	

C. ECONOMICS

1. PLANT ECONOMICS

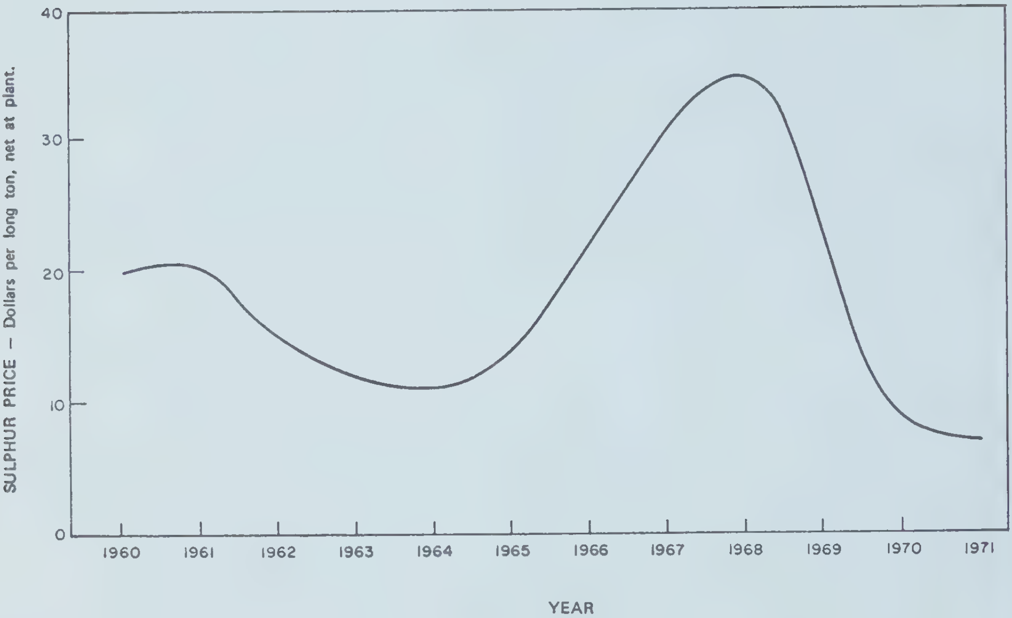
Production statistics for 1971 indicate that more than 55% of the gas processed in Alberta is obtained from sour gas fields. Sour gas and its attendant sulphur plants are an important segment of the Alberta and Canadian energy scene. Unfortunately, however, at the present gas and sulphur prices sour gas plants have become less and less attractive from an economics viewpoint.

Revenues to be received from condensate, LPG and natural gas can be estimated with a satisfactory degree of accuracy for the evaluation of a gas processing plant investment. Plants processing sour gas however, and receiving a considerable portion of their revenue from the sale of sulphur pose a prediction dilemma. The per cent of the total plant income from sulphur production increases as the gas increases in acid gas content and as the gas become dryer. At present sulphur prices, very sour natural gas decreases the quantity of residual gas and L.P.G.'s available for sale and at moderate to high concentrations is capable of reducing income to the point of making the projected operation an economic failure. Industry and indeed company estimates are at considerable variance concerning the future price of sulphur. The present price performances of sulphur Figure I-10 and the projected future growing oversupply (Figures I-11,12) are considerations which indicate no early increase in sulphur prices is to be expected.

2. ECONOMIC BENEFITS TO ALBERTA

The benefits to Alberta from the natural gas industry are well documented. Expenditures in the province during 1971 are detailed below. For 1971 gross production revenues from natural gas were $465 MM or 30% of the petroleum industry revenue of

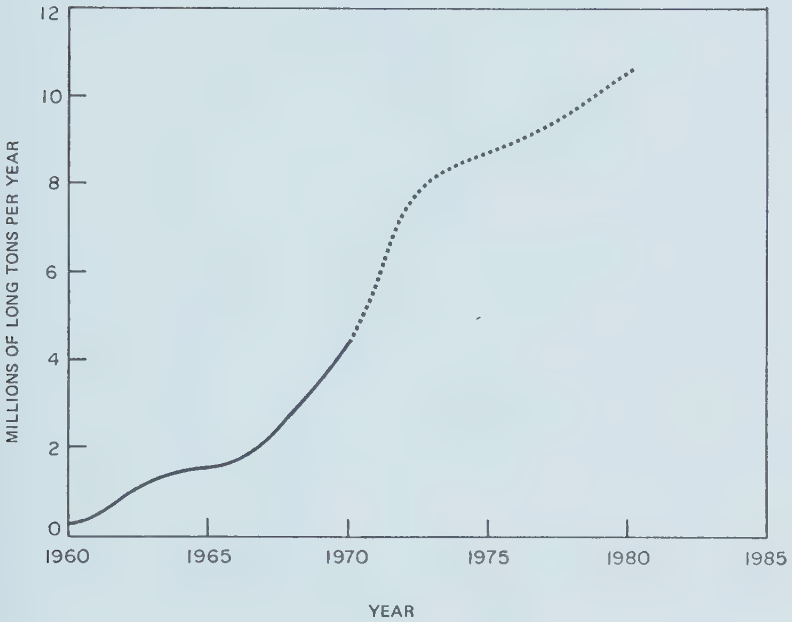
NET PLANT PRICE OF ALBERTA SULPHUR



Source: Alberta Energy Resources
Conservation Board.

Figure I

PRESENT & PROJECTED ALBERTA SULPHUR PRODUCTION



Source: Alberta Energy Resources Conservation Board.

Figure I - II

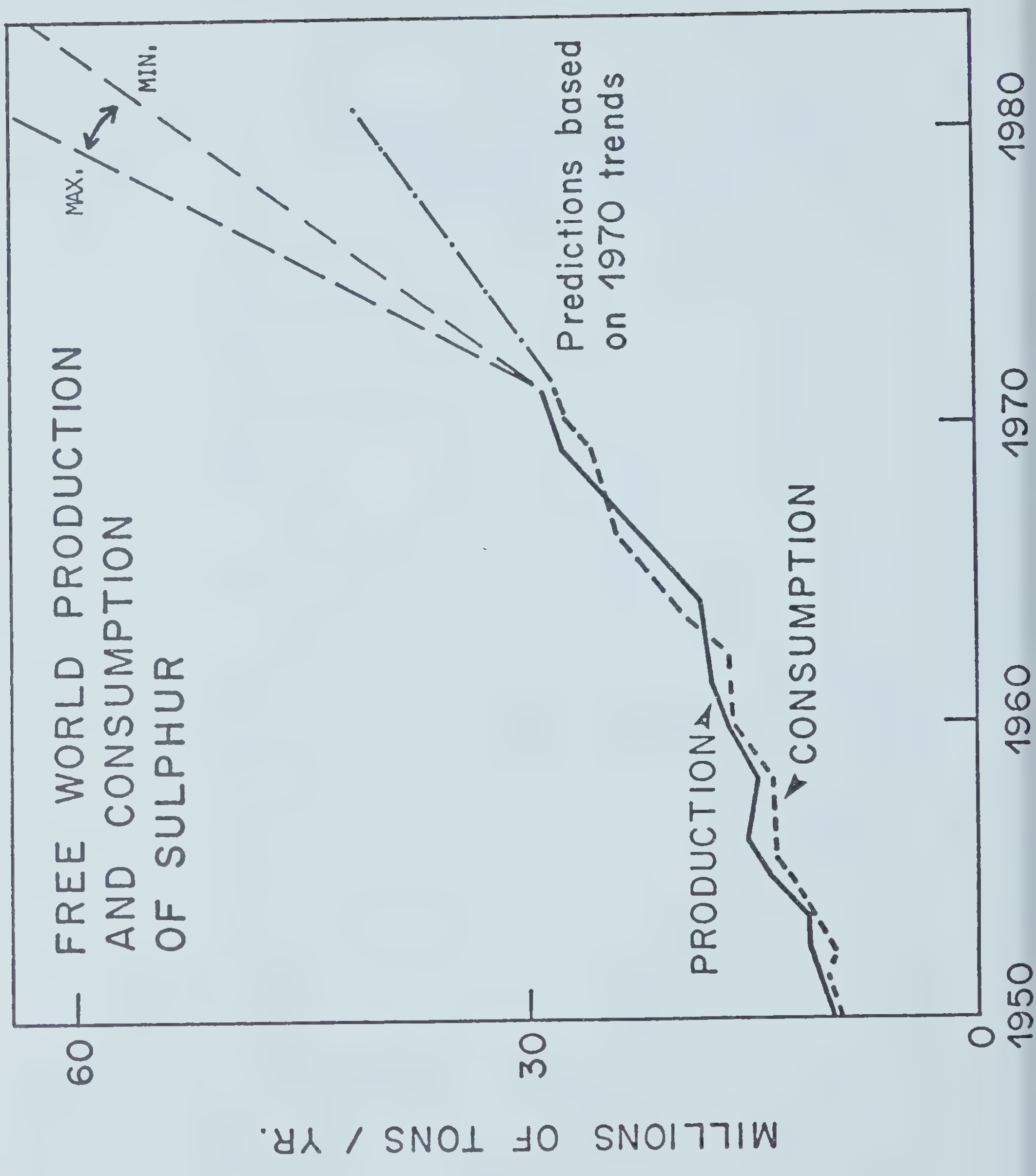

FREE WORLD PRODUCTION
AND CONSUMPTION
OF SULPHUR
MAX.
MIN.
Predictions based
on 1970 trends
PRODUCTION
CONSUMPTION
60
30
0
MILLIONS OF TONS / YR.
1950
1960
1970
1980

Figure I-

$1555 MM.

NATURAL GAS INDUSTRY REVENUES AND EXPENDITURES 1971

	REVENUES 1971		1971 EXPENDITURES
		EXPLORATION	$26*
		DEVELOPMENT	12*
		LAND	18*
NATURAL GAS	$263 MM	PRODUCTION FACILITIES	16*
GAS LIQUIDS	183	GAS PLANTS	207
SULPHUR	19	PRODUCTION COSTS	64**
		ROYALTIES	59**
		OTHER	30**
	$465 MM		$432 MM

* Based on industry expenditures Oilweek February 21, 1972 prorated to natural gas on the basis of reserves discovered

** Based on industry expenditures Oilweek February 21, 1972 prorated to natural gas on the basis of production value.

A major portion of industry expenditures are made in Alberta and create jobs not only in the industry but also through the "multiplier" effect for Canadians and Albertans. A study of E. J. Hanson, Professor of Economics at the University of Alberta in 1966 concluded that the petroleum industry directly and indirectly was responsible for generating 47% of the total personal income of Albertans in 1964. The increase over the years in the contributions by the petroleum industry to personal income is illustrated in the following Table:

PERCENT OF TOTAL PERSONAL INCOME IN ALBERTA

INDUSTRY	1947	1952	1957	1964
PETROLEUM	5	28	45	47
AGRICULTURE	75	56	37	35
OTHER	20	16	18	17
	100	100	100	100

Reference: E. J. Hanson, Regional Employment and Income Effects of the Petroleum Industry in Alberta.

We would estimate that currently 50% of personal income in Alberta has as its base the petroleum industry and that 30% of this figure is attributable to the gas producing and processing segment.

Presently oil and natural gas revenues constitute 21% of the gross provincial product while 30% of the revenue raised by the provincial government from within the province is supplied by the oil and gas industry.

D. INDUSTRY SAFE OPERATING PRACTISES

1. GENERAL

All drilling and production operations whether they pertain to hydrogen sulfide involvement or not, are subject to both government regulations and company standards and practices. Regulations governing drilling, production and pipelines are administered by the Energy Resources Conservation Board. Operations within forested areas are scrutinized by the Department of Lands and Forests. The Department of the Environment has jurisdiction over phases of drilling and production operations as they affect the environment. Regulations of these three government bodies cover safety aspects and prudent operation of wells and pipelines to minimize environmental disturbances and maximize environmental protection. The gas industry has developed and uses many programs and standards in excess of the general government standards to provide for the safety of personnel, residents of the area, and for the protection of the environment.

2. DRILLING

During drilling, contamination of potable subsurface water is prevented by installing and cementing surface casing to a depth below the zone of interest or at least equivalent to 10% of the well's projected depth. Surface pollution from the drilling operation is prevented by maintaining proper drilling fluid systems, by the use of blowout preventers, and by adequately disposing of mud, cuttings and debris native to the operation.

Mud properties are carefully controlled to maintain an optimum drilling rate and still control formation pressures. If a blowout (formation fluid flowing into the well bore) occurs, the drilling rig is equipped with blowout preventers which can be closed to shut in the well. On completion of the well the drilling fluid is separated into liquid and solid portions. The liquid is approved for disposal based on the chemical composition following treatment. The dried solids are buried in the mud storage pit and the drilling site is restored subject to ERCB, Department of Lands and Forests and Department of Environment approval.

3. PRODUCTION OPERATIONS

In dealing with very sour wells employees work in pairs with emergency equipment available in their truck. Some operations have regular radio checks to keep the plant office in touch with field personnel.

Recent regulations by the ERCB require that safety shutdown valves be installed in the tubing of sour gas wells. These valves must be located at least 100 feet below the surface and automatically shut off the tubing in the event of uncontrolled rates of flow. In addition, sour gas wells are equipped as required with low and high pressure actuated shutdown valves on the well head to protect the transmission line from excessive pressures and to shut in the well in the event of a line failure.

4. PIPELINE

The pipelines which transport the well bore fluids to the plant may be subject to failure caused by excessive pressure, corrosion, both interior and exterior, and mechanical interference.

Specifications for pipe for sour service are quite rigid. Experiments and experience have provided metallurgy and testing techniques which are used by the industry to provide safe and efficient sour gas transmission. These include pipe material specifications, hardness, manufacturing processes, welding techniques and inspection, such as X-ray and pressure testing.

Virtually all sour gas pipelines are externally coated and cathodically protected to minimize exterior corrosion. Interior corrosion is controlled by use of one of many types of corrosion inhibitors injected into the pipeline or peridoically batched through it. As corrosion cannot be completely controlled, operators carry out extensive corrosion monitoring programs. Corrosion coupons and hydrogen probes are used to measure interior corrosion rates and evaluate inhibitor programs. Bell holes, ultrasonic and X-ray inspection are used to monitor interior and exterior corrosion. Test spools are also used.

Regular leak detection surveys are also carried out.

5. PLANT OPERATIONS

a. General

Gas precossing plants are potentially dangerous work environments. The plants handle inflammable, poisonous fluids under high pressure, using high voltage electrical equipment, heavy equipment and rotating machinery, steam and chemicals. The gas industry and government have recognized these potential hazards and have set up stringent regulations and extensive safety programs that have succeeded in minimizing plant health hazards and accidents. The Workmen's Compensation Board assessment rates, Table I-6, are a reflection of the costs of accidents and are directly related to the severity and number of accidents in various industries. The sour gas processor have always emphasized safety and the low assessments for gas plants indicate that this policy has been successful.

Some gases are recognized as dangerous substances to be handled with respect. Every company working with very sour gas gives their personnel instruction and training on the detection of H_2S, rescue, safety and first aid procedures, as well as training to deal with any plant or field emergency involving this gas. Safety and rescue equipment must be readily accessible, and periodically checked to insure that it functions properly. Safety drills are conducted to simulate emergency situations to familiarize personnel with corrective measures. Every plant processing sour gas is required to have an emergency procedure to deal with an uncontrolled flow of sour gas to protect personnel, area residents and process or field equipment.

Principle hazards in gas plants are failure of pressure equipment, fire, electrical shock, mechanical equipment failure,

TABLE I - 6

WORKMEN'S COMPENSATION BOARD ASSESSMENT RATES

1972 (per $100 of payroll)

1.	Underground coal mining	$ 9.00
3.01	Logging, pulp and paper	$ 8.00
3.02	Lumber mills	$ 5.00
39.46	Farming	$ 5.00
6.07	Highway construction	$ 3.50
6.01	General oilfield construction	$ 2.75
6.03	Painting, plastering	$ 2.50
15.09	Oilfield service	$ 2.25
6.02	Plumbing	$ 1.80
89.01	Employment by towns, villages	$ 1.70
	Employment by cities	$ 0.95
2.01	Garage and service stations, auto repairs	$ 1.20
39.08	Hotels, restaurants, drive-ins,catering	$ 0.80
15.11	Refineries, absorption plants	
*	includes gas plants	$ 0.60
11.02	Hardware, sporting goods stores	$ 0.40
11.01	Department stores, drug stores	$ 0.20
15.08	Operation of gas or oil wells	$ 0.15

H_2S inhalations, chemical burns or inhalation and noise. Plant safety is concerned with prevention of accidents and minimizing the effects of accidents. Following are references to critical plant areas of concern.

(b) Explosions and Fire

A number of professional and governmental agencies have regulations and procedures for the standards of construction, among these are the Alberta Boilers Branch, American Society of Mechanical Engineers, American Petroleum Institute, American Society for Testing Materials, National Building Code, Canadian Electrical Code, Alberta Electrical Code, Canadian Standards Association, American Standards Association, American National Standards Institute, Canadian Insurance Underwriters, Workmen's Compensation Board and Department of Labor. These groups set standards for pipes, valves, fittings, vessel design and fabrication, installation, testing and maintenance. In addition, a regular program of corrosion control and monitoring as well as maintenance programs are carried out. Some plants have installed gas leak detectors and fire detection systems which in some cases are tied into plant safety and shutdown systems. The operators of gas plants have built up an extensive technology which is incorporated into the construction of the plant to increase safety and decrease the probability of equipment failures.

Individual companies and insurance underwriters have set standards regarding spacing and equipment and fire protection measures. Electrical conduits are sealed when entering hazardous areas to prevent explosions from traveling between areas. Plants are laid out to separate various pieces of equipment and processes to prevent fire damage in one area from spreading to another. Fire shutdown systems and 'panic buttons' are installed to decrease the fire size and spread. Fire extinguishers and fire water systems are provided as required.

All employees are trained in fire drills for which the employee responsibilities and procedures are set out. Trained first aid personnel and equipment are available. At larger plants ambulances are available and the emergency procedures detail routes to hospitals, etc.

c. H_2S Inhalation

Hydrogen sulphide is an ever-present hazard in sour gas plants. Safety meetings and equipment demonstrations are provided to keep the employees up to date. Work procedures are arranged so that men in hazardous area work in pairs or groups. When working on equipment that involves venting even small quantities of hydrogen sulphide, air masks are required. In buildings, warning lights are activated if maintenance is being done where H_2S may be vented.

Buildings containing sour gas are supplied with forced ventilation to prevent accumulations of H_2S. Maintenance procedures are set out to be followed to ensure safe working habits.

Plant designs incorporate open and closed drain systems. The closed door drain system prevents H_2S vapours from accumulating in the plant area.

Prompt action is the key to saving a man who has been knocked unconscious by hydrogen sulphide. Every employee is instructed on rescue procedures and one or more resuscitators complete with oxygen bottles are always available.

d. Chemical Burns

Special instructions are given for the handling of dangerous chemicals and special handling equipment and protective clothing are provided if required. Some of the chemicals involved are sulphuric acid, sodium hydroxide, amines, lime, bacteriacides, fungicides and herbicides. Eyewash fountains and showers are provided, and First aid personnel are available to help in the event of a mishap.

e. Noise

There is considerable evidence that excessive noise can cause progressive hearing loss. Plant noise levels and employee exposures must be below the requirements of the Department of Labor. Noise surveys may be carried out as a matter of course and hearing protection is available, when required, for extended periods of work in noisy areas. More attention is being paid to the design of facilities and equipment to lower noise levels. Some companies have begun regular tests of employees exposed to high noise levels on a regular basis to ensure that hearing is not being impaired.

f. H_2S and SO_2

The American Conference of Government and Industrial Hygienists has set limits for these gases in work areas. Threshold limit values or values acceptable eight hours a day, five days a week, have been set at 10 PPM for hydrogen sulphide and 5 PPM for sulphur dioxide. No work area limits have been set by government in Alberta. Air contaminants in sour gas plants are not to be compared with urban smogs. The chemical composition of smogs, etc., is very complex while a gas plant environment is much simpler. All evidence to date indicates that hydrogen sulphide and sulphur dioxide are not cumulative poisons and do not accumulate in the body. There is no evidence to indicate that the levels of hydrogen sulphide or sulphur dioxide usually encountered in gas plants can be connected with a progressive deterioration of health.

Hydrogen sulphide and sulphur dioxide in high concentrations cause eye irritation, lung irritation, headaches and can be fatal. Employees likely to be exposed to such high concentrations in specialty operations are required to wear air masks.

g. COS and CS_2

COS and CS_2 are present in some sour gases and plant tail gas as trace components. These are not health hazards in the concentrations encountered. Any employee exposed to dangerous concentrations of these agents from the gas stream has already been exposed to a fatal concentration of hydrogen sulphide or sulphur dioxide.

CS_2 is used as a solvent to dissolve sulphur deposits in flow lines and downhole equipment. It is handled as a toxic chemical with toxic fumes. Department of Labor and company regulations cover the handling, use, and storage of this chemical.

h. Electrical

The Canadian and Alberta Electrical Code provide extensive regulations that ensure that safe systems are installed. Most gas plants have buried wiring to eliminate the hazards of overhead wiring. Basically no employees other than electricians are allowed to work with live electrical equipment. Special controls and

and systems are required in hazardous areas.

i. Other

Selenium and lead have never been detected in natural gas plant waste streams. Phenols, glycols, mercury and mercaptans may be found only in trace quantities and are not considered to be a health hazard.

All plant employees are encouraged to take first aid training and these courses are made available to employees through the St. John's Ambulance Society and Workmen's Compensation Board. First aid rooms and supplies are situated in the plants with competent men available to handle first aid situations. Programs of safety glasses, hats and steel-toed boots are in effect. All operators investigate all lost-time accidents to determine the causes and make recommendations to prevent such future accidents and injuries.

The record of gas processors with respect to in-plant safety speaks for itself. This position has not been achieved without considerable effort on the part of employees and industry organizations. Industry health and safety programs are an essential part of the operation of sour gas plants. These programs will continue in the future to deal with existing problems and to investigate and deal with any new areas of health concern that arise.

E. PLANT UPSETS

Interference in or disruption of the plant processing operation causing a "plant upset" condition is usually cited as an event responsible for abnormal emissions of sulphur compounds. Plant upsets generally are infrequent occurances but also are a fact of life to be expected in the continuous operation of a multi-million dollar complex of valves, piping, vessels, pumps, motors, furnaces, etc., handling varying loads of gas and liquid often in varying compositions under high pressures.

In sour gas plants, plant upsets usually cause sales gas to go off specification as regards H_2S content, and process streams must be diverted to the relief system and flare. Although instrumentation and alarms signal immediately the cause of the upset, permitting reduction or cessation of plant intake, even in the minor upset categories reconditioning of the plant system to "on spec" conditions can take considerable time. Often, in addition to time spent to correct the cause of the upset, lines must be depressured and absorbing chemicals reconditioned before a plant train can be returned to service.

Plant upsets are an inconvenience to the operator and in some instances a nuisance to plant area residents. In an endeavor to reduce the latter situation, high relief stacks with a perpetual flame are in service to emit and burn waste gases. Fuel gas is usually added to the waste gas to insure complete combustion of hydrogen sulphide to sulphur dioxide. These actions are the only practical methods available to date for handling these situations. In actuality, operators should be commended for their excellent record in maintaining plant operations under planned maintenance controls and schedules and reducing upsets in frequency and duration to the levels now experienced.

F. SULPHUR STORAGE AND TRANSPORATION

Solid chemical sulphur is a remarkably friable material that is not totally chemically inert as far as interaction with the environment is concerned. For these reason problems of its storage and transportation can arise. Both have been tackled with some success by the industry as inventories have increased and distrant markets have been sought. Research continues to improve both atorage and handling techniques.

Sulphur is generally stored in Alberta and elsewhere in solid form and until recently, virtually all sulphur production in Alberta was cast into solid storage blocks at the plant site. These storage blocks were mechanically stable and dusting problems were primarily associated with loading and transportation. Chemical reaction with environment is primarily the result of interaction with water and air to yield oxidation products which are acidic in character. The range of contamination by these products of reaction of sulphur with environment is generally limited, however, and containment to the immediate vicinity of the plant operation has been generally good.

The sulphur dust problem associated with loading and transportation has been tackled by moving to "formed sulphur" and in particular, slated sulphur. This technique was introduced generally in Alberta in 1971 and the bulk of Alberta solid pro duction sold, is now being slated. Research is continuing to attempt to improve the resistance to breakdown of formed sulphur and to examine the effects of aging which may well become significant if Alberta sulphur inventories continue to grow.

The bulk of Alberta sulphur shipments throughout North America are in liquid form. The industry recognised early the problems associated with the evolution of hydrogen sulphide from liquid sulphur during its storage and transportation. This problem has been successfully resolved and modifications continue to be made to minimise environmental contaminations from this source.

Work on the development of techniques for the pipeline transportation of sulphur is in progress. This is a potentially important future development which may well bring Alberta's massive sulphur resources closer to world markets.

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II SULPHUR & SULPHUR COMPOUNDS - ENVIRONMENTAL EFFECTS

A. INTRODUCTION

(1) Scope

This section of the brief considers the effects of sulphur bearing compounds on: vegetation, animal and human health.

Primary consideration has been given to sulphur dioxide in view of the wide distribution of this compound in the atmosphere. Hydrogen sulphide will be briefly considered only, as it is normally oxidized to sulphur dioxide prior to discharge with combustion products from industrial process stacks. Mercaptans constitute a potential local odor problem but do not affect vegetation. In addition, the effects, of air and water transported sulphur dust, on soils and ground waters are reviewed.

The sources of sulphur compounds and their role in the natural cycle will be considered briefly.

(2) Sources of Sulphur Compounds in the Atmosphere

Sulphur compounds are introduced into the atmosphere from a variety of natural and man-made sources. These compounds consist of sulphur dioxide, hydrogen sulphide, and oxidation or reaction products such as sulphuric acid and sulphates. The global circulation of sulphur compounds follows an intricate pattern in relation to the sulphur content of soils, vegetation, water (in rivers, lakes and oceans) and the atmosphere. Sulphur is released from the weathering of igneous and sedimentary rocks, from the bacterial decomposition of organic matter in soils, rivers, lakes and oceans and from combustion of fossil fuels and various industrial operations.

The yearly circulation of S has been documented by numerous investigators through mathematical global models (1, 2, 3). The total amount passing through the atmosphere is estimated at 365 million tons per year. The industrial emission at present makes up only 11 percent of the total.

The principal sources of industrial sulphur dioxide are the combustion products of sulphur-containing fossil fuels to provide electric power, steam and heat; the smelting of sulphide ores, refining of petroleum products, sour gas processing, coke processing, sulphuric acid manufacture, and many other operations that utilize raw materials containing sulphur. Estimates in Table II-1 indicate the approximate emissions of sulphur dioxide to the atmosphere in 1969 in Canada from the combustion of fossil fuels.

Natural sources of atmospheric sulphur dioxide, many times greater in quantity than the emissions from industrial operations, are derived from the death and decay of vegetation of land and plankton in the oceans, as well as from animal organisms. In this natural sulphur cycle, the sulphur may be released as hydrogen sulphide which is oxidized to SO_2 in the atmosphere. Active volcanoes release large quantities of sulphur dioxide to the atmosphere, including emissions from fumeroles and vents that are often found in volcanic regions.

TABLE II-1

Estimates of sulphur Dioxide Emissions in Canada in 1969 from Combustion of Fossil Fuels

(Data on Consumption of Fossil Fuels and Petroleum Products from Statistics Canada)

SOURCE OF COMBUSTION	SULPHUR DIOXIDE EMISSION SHORT TONS
COAL	895,000
LIGHT FUEL OIL, NOS. 2 AND 3	270,000
HEAVY FUEL OIL, NOS. 4, 5 AND 6	689,000
DIESEL FUEL	32,800
MOTOR GASOLINE	73,600
KEROSENE, STOVE AND TRACTOR FUEL	16,300
NATURAL GAS	169
TOTAL	1,976,869

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NATURAL GAS	169
TOTAL	1,976,869

(3) Role of SO_2 in Life Cycle

Sulphur dioxide in low concentration is a natural and essential component of the atmosphere, like carbon dioxide. Life would be impossible without sulphur and it is, therefore, an essential element for the growth of vegetation. It is a vital constituent of proteins and is present in many biologically active compounds such as methionine, cystine, glutathione, thiamine and thioctic acid. The sulphur in leaves consists mainly of two forms, an organic sulphur fraction and inorganic sulfates. Whether the sulphur is absorbed from the soil through the roots as soluble sulphate or through the leaves from the air as sulphur dioxide, the final disposition of the element is the same in the case of non-toxic concentrations. However, sulphate from the soil is more effective as a nutrient than is airborne sulphur dioxide because of the greater mobility of sulphate in the plant.

On the average, one sulphur atom is necessary for every 16 nitrogen atoms, or one part by weight of sulphur for every 7 parts by weight of nitrogen. In the global cycle of sulphur, by far the largest amount of sulphur dioxide and sulphate is supplied by the oxidation in the atmosphere of hydrogen sulphide, released by the decay of plant life and decomposition of organic matter. This sulphate is returned to the land and the sea by rain and other forms of absorption and deposition.

Although coastal areas receive substantial amounts of sulphate from rain contaminated with ocean spray, inland continental areas are entirely dependent on sulphur oxides in the atmosphere and supplements through use of fertilizers. An average forest requires 20 lbs. of sulphur per acre for new growth. About 15 lbs. per acre is returned to the soil in fallen leaves and branches. The net requirement is, therefore, 5 lbs. per acre plus the amount lost in drainage. Farm crops require more sulphur and some, like cabbages, need as much as 40 lbs. per acre.

In Central Alberta, rain and snow analyses suggest, according to a report by Summers and Hitchon(4) of the Research Council of Alberta, that between 2 and 6 pounds of sulphur (as sulphate) per acre are being deposited annually. Present levels of sulphur oxides in the atmosphere of Central Alberta would seem to be contributing insufficient sulphur to eliminate the deficiency which exists in this area.

B. VEGETATION

(1) Relative Susceptibility to Sulphur Dioxide

Extensive studies of the effects of this gas on susceptible species of plants have been published by Katz, et al (5,6,7) and by Thomas and co-workers.(8,9,10) Different species of plants vary widely in their susceptibility to damage by sulphur dioxide. These differences appear to be due principally to variations in the rate of absorption of this gas by their leaves. Sensitive plants are those with succulent leaves of high physiological activity, such as alfalfa, cotton, barley, rye, spinach and rhubarb. Plants with fleshy leaves and needles are inclined to be more resistant, except when they are freshly or newly formed.

The susceptibility of green plants to sulphur dioxide is dependent upon concentration, duration and absorption factors, as influenced by a variety of environmental conditions. Leaves of plants are more sensitive to gas during periods of active growth, optimal soil mixture, daylight hours, summer temperatures above 40°F and below 85°F, and in other environmental conditions that favour a high rate of photosynthesis, transpiration and absorption. Conversely, the resistance of plants to gas increases with age, in darkness, in the period of dormancy extending from autumn through the winter and early spring months, and during periods of drought and excessive temperatures in the growing season.

Conditions in the environment that cause the stomata of the leaves to remain open will enhance the absorption of gas and render a particular species more susceptible to injury. These include high relative humidity, high light intensity (especially in the morning hours), adequate moisture supply from the soil and moderate temperatures. The existence of a relationship between the diurnal trend of stomatal aperatures and susceptibility in plants was demonstrated by Katz et al.(2) Most species of plants close their stomata at night and are, therefore, much more resistant than in daylight. The stomata also close under conditions of moisture stress (low relative humidity and inadequate soil moisture).

The following data (Table II-2) indicate the effect of decreasing relative humidity on alfalfa and other susceptible plants. If maximum sensitivity at 100% relative humidity is assigned a factor of 1.0, the resistance to SO_2 increases by a factor of ten in an environment of dry air.

TABLE II-2

Effect of Relative Humidity on Susceptibility to SO_2 (M. D. Thomas)

RELATIVE HUMIDITY PERCENT	RELATIVE RESISTANCE TO SO_2 INJURY
100	1.0
80	1.12
60	1.30
50	1.45
40	1.85
30	3.2
20	5.5
10	7.7
0	10.0

The relative susceptibility of many plants to SO_2 is illustrated by the data in Table II-3, compiled by Thomas and Hendricks.(10) The factor of 1.0 has been allotted to the most sensitive plants, such as barley, alfalfa and rye. Higher factors in other species indicate increasing resistance. These factors have been adjusted to correspond to optimum environmental conditions that would promote maximum sensitivity to SO_2.

(2) Scientific Criteria for Effects of SO_2 on Plants

(a) Sulphur Levels in Leaves - Laboratory Investigations

Plants exposed to atmospheric sulphur dioxide concentrations during the growing season will show an accumulation of sulphur in healthy leaves. Katz(5) has stated: "Unless the concentration and exposure to gas and other (environmental) factors are known accurately, there is no quantitative relation between the increase in sulphur levels of plant tissue and the degree of injury, because the sulphur content is subject to great variation in normal plants". Many later investigators have confirmed Katz's conclusions, that foliar sulphur levels are not related to damage by sulphur dioxide. Some of these are Berry, G. R. et al (11), Viel, M. G. et al (12), Garber, K. (13), Wentzel, K. F. (14), and Bjorkman, E. (15). Guderian (16) found that sulphur levels continue to fluctuate in the green photosynthesizing tissue of partially killed needles, whereas sulphur levels remained steady in the killed portions of such needles. Guderian further reported that foliar sulphur levels decrease after cessation of fumigations and are, therefore, not only dependent on rates of sulphur assimilation during fumigations but also on frequency and duration of sulphur dioxide free periods

TABLE II-3

Relative Sensitivity of Cultivated and Native Plants to SO_2 Injury

SENSITIVE		INTERMEDIATE		RESISTANT	
		-cultivated plants-			
Alfalfa	1.0	Cauliflower	1.6	Gladiolus	2.6
Barley		Parsley		Horse-radish	
Endive		Sugar Beet		Sweet Cherry	
Cotton		Sweet William		Rose	2.8 - 4.3
Rye					
Cosmos	1.1	Aster		Potato	3.0
Rhubarb		Tomato	1.3 - 1.7	Castor Bean	3.2
Sweet Pea		Eggplant		Maple	3.3
Radish	1.2	Parsnip		Boxelder	
Verbena		Apple	1.8	Wisteria	
Sweet Potato		Cabbage	2.0	Mock Orange	3.5
Spinach		Hollyhock	2.1	Onion	3.8
Buckwheat	1.2 - 1.3				
Bean	1.1 - 1.5	Peas		Lilac	
Broccoli	1.3	Gooseberry		Corn	4.0
Brussels Sprouts		Marigold		Cucumber	4.2
Pumpkin		Leek	2.2	Crysanthemum	5.3 - 7.3
Table Beet		Begonia		Celery	6.4
Oats		Grape	2.3	Citrus	6.5 - 6.9
Clover	1.4	Linden		Cantaloupe	7.7
Rye Grass	1.4				
Squash		Peach		Live Oak	14.0
Carrot	1.5	Apricot		Privet	15.0
Turnip		Elm	2.4		
Wheat		Birch			
		Plum	2.5		
		Poplar	2.5		

between fumigations. Hence the timing of sampling for sulphur level determinations after exposure to sulphur dioxide becomes an additional variable factor. There is another complicating factor. Long periods of uninterrupted exposure to very low levels of sulphur dioxide cause greater increases in foliar sulphur levels than shorter periods of exposure to higher but still sublethal levels of sulphur dioxide (Guderian 16).

It is clear that foliar sulphur contents cannot be used as a measure of damage by sulphur dioxide. However, given a steady source of sulphur dioxide emissions, foliar sulphur levels may be indicative of the extent of sulphur dioxide dispersion. Katz (6) has noted: "Nevertheless, such data (foliar sulphur contents) from comprehensive collections of certain sensitive plants, may be used to define the area within which the gas occurs". Today, this is indeed the only "practical" use that can be made of knowledge of foliar sulphur contents obtained from field samples.

Loman (17) has reported that results of a cooperative study of the Alberta Forest Service and the Provincial Air Pollution Control Division showed that pine and spruce foliar sulphur contents fluctuated upwards in the vicinity of sour gas plants for 3 to 5 years, after which they fluctuated down again to levels found at the time the gas plants went into production, whereas foliar sulphur contents of aspen and poplar continued to fluctuate upwards (Ullman 18). From a biological point of view, the fluctuations in foliar sulphur levels in pine and spruce after 3 to 5 years exposure to sulphur dioxide may be ascribed to any of a considerable number of uncontrollable factors of the environment about which we have no information. From a practical point of view, sulphur dioxide emissions near the sour gas plants investigated by these agencies have up to now obviously been below the lethal level for the main tree species.

(b) Field Observations

The following data, (Table II-4) compiled by Dreisinger (19) and McGovern, indicate the minimal intensity factors prevailing at the time that recorded ground concentrations and durations caused injury to various species of agricultural and forest growth. The plant species are listed in order of increasing resistance to SO_2. It is apparent that buckwheat and trembling aspen are the most sensitive species in the Sudbury District, with a minimal intensity value of 74. These data represent correlations between field observations on the condition of crops, shrubs and trees and gas concentrations recorded at the nearest SO_2 monitoring stations.

Intensity numbers were assigned to the above exposure limits on the basis of 100 being equal to the approximate threshold limit for injury under optimum sensitivity conditions for the most susceptible species of vegetation. Thus an average concentration of 0.95 ppm for one hour, or 0.55 ppm for two hours, or 0.35 ppm for four hours, or 0.25 ppm for eight hours would in each case be equal to a potential intensity of 100. Intensities above or below these limits of concentration and duration of exposure could then be computed by this formula.

A total of 5,602 fumigations recorded in the Sudbury area were analyzed on the above basis. Of these, 622 reached or exceeded the above theshold levels potentially capable of causing injury to vegetation. However, many of the 622 recorded fumigations did not cause any injury to susceptible species as they occurred either too early or late in the

TABLE II-4

Minimal average SO_2 concentrations recorded after which injury to vegetation was observed in various species and maximum intensities to which the species were exposed at other times with no resultant injury (Dreisinger and McGovern)

Species	Max. av. conc. (ppm for				Intensity Number	Max. intensity to which species exposed with no resultant injury
	1 hr.	2 hr.	4 hr.	8 hr.		
buckwheat	0.56	0.39	0.26	0.15	74	-
red clover	0.60	0.50	0.33	0.17	94	332
oats	0.63	0.59	0.34	0.17	107	294
peas	0.63	0.59	0.34	0.17	107	276
rhubarb	0.63	0.59	0.34	0.17	107	276
timothy	0.66	0.54	0.40	0.21	114	240
swiss chard	0.88	0.64	0.42	0.27	120	268
beans	0.46	0.45	0.43	0.21	123	272
beets	1.31	0.77	0.45	0.23	140	272
turnips	1.31	0.77	0.45	0.23	140	272
carrots	1.08	0.79	0.50	0.25	144	276
cucumbers	1.08	0.79	0.50	0.25	144	276
lettuce	0.64	0.56	0.43	0.38	152	276
radish	0.64	0.56	0.43	0.38	152	276
squash	0.64	0.56	0.43	0.38	152	157
tomatoes	0.64	0.56	0.43	0.38	152	272
potatoes	0.64	0.56	0.43	0.38	152	332
raspberry	0.74	0.63	0.53	0.39	156	332
celery	0.87	0.74	0.55	0.29	157	240
spinach	1.34	0.91	0.50	0.34	166	276
cabbage	0.94	0.89	0.70	0.45	200	332
corn	never injured[a]					294

[a] near recorder stations

TABLE II-4 (Continued...)

Minimal average SO_2 concentrations recorded after which injury to vegetation was observed in various species and maximum intensities to which the species were exposed at other times with no resultant injury (Dreisinger and McGovern)

Species	Max. av. conc. (ppm for				Intensity Number	Max. intensity to which species exposed with no resultant injury
	1	2	4	8		
			- Forest Species -			
trembling aspen	0.42	0.39	0.26	0.13	74	450
jack pine	0.52	0.44	0.29	0.20	83	143
bracken fern	0.45	0.34	0.25	0.21	84	209
white birch	0.46	0.38	0.28	0.21	84	450
white pine	0.45	0.35	0.25	0.21	84	224
larch	0.41	0.38	0.34	0.26	104	160
large-toothed aspen	0.66	0.43	0.37	0.20	106	450
willow	0.41	0.38	0.33	0.30	120	332
alder	0.46	0.43	0.43	0.21	123	332
red pine	0.78	0.69	0.44	0.30	126	432
Austrian pine	0.66	0.45	0.44	0.33	132	432
hazel	1.14	0.75	0.45	0.23	136	192
balm of Gilead	0.95	0.68	0.61	0.38	175	332
cedar		never injured[a]			-	224
spruce		never injured[a]			-	450
maple		never injured[a]			-	450

[a] near recorder stations

Intensity numbers (1) 105 x for 1 hr. where X represents SO_2 in ppm
(2) 182 x for 2 hrs. " " " " " "
(3) 286 x for 4 hrs. " " " " " "
(4) 400 x for 8 hrs. " " " " " "

growing season, or during periods when the vegetation was comparatively resistant to SO_2. Only on nine occasions was injury observed after exposure to SO_2 during which the average concentrations were lower than the listed potential limits. In every instance, such injury occurred with fumigations during the critical months of June and July in periods of high humidity and environmental factors favouring maximum susceptibility.

(c) Vegetation Tolerance Limits

Detailed studies on the effects of sulphur dioxide on photosynthesis, respiration, rate of growth and yield of the most sensitive plants, such as alfalfa, by Katz et al, and by Thomas and co-workers have lead to the following findings:

(1) About 0.30 ppm applied to the plants for four hours per day for a month had no effect.

(2) A whole crop of alfalfa was grown under continuous fumigation with an average concentration of 0.10 ppm for 504 hrs. and in another experiment, with continuous fumigation at 0.11 ppm for 602 hrs., without producing any injury and with no effect on photosynthesis, rate of growth and yield.

(3) A 45-day continuous fumigation of alfalfa at an average concentration of 0.10 ppm showed no effect on carbon dioxide assimilation or growth.

(4) At higher concentrations, 0.40 to 0.60 ppm for 4 hours, it was found that alfalfa showed a small reduction in carbon dioxide assimilation but

complete recovery occurred within about two or three hours after the fumigation was discontinued.

(5) Under optimum environmental conditions for susceptibility, the first light symptoms of injury may occur in a fumigation of alfalfa with about 1.25 ppm in one hour.

On the basis of an extensive review of scientific evidence on the effects of sulphur dioxide on sensitive species of plants, the State of California adopted the following ambient air quality standards at the "adverse level" (15):

1.0 ppm for one hour, in daylight
0.30 ppm for eight hours, in daylight

(2) Effects of H2S

Hydrogen sulphide is usually not toxic to plants except in high concentrations greater than about 10 to 20 ppm. This gas has an offensive odour in concentrations as low as 0.05 ppm and may be detected by smell in the vicinity of oil refineries and draft pulp mills. Although it tarnishes metals and discolors paint at low concentrations, there is little, if any, evidence that this gas causes significant injury to field crops.

C. ANIMAL LIFE

Early interest in this subject was concerned mainly with diseases and mortality in farm animals arising from the emissions of toxic metals from metal smelting and refining operations and the phosphate fertilizer industry. In the early history of base metal smelting, cases of litigation developed over poisoning of livestock by arsenic, lead and some other heavy metals. However, the development of adequate methods of source control have virtually eliminated this hazard to animals. There are no substantiated cases on record of injury to farm animals from emissions of sulphur oxides in the metal smelting and refining industry in the last forty years. It is only within recent years that laboratory studies have been undertaken on a systematic basis to determine the toxic effects of animals of specific air pollutants commonly found in the community atmosphere. This interest has developed out of concern for the effects of air pollution on human health. Pollutants presently under investigation include sulphur dioxide, sulphuric acid nitrogen oxides, ozone and oxidants, carbon monoxide, aldehydes, organic peroxides and various potentially carcinogenic compounds.

With regard to the harmful effects of air pollution on animal health, the evidence of major air pollution disasters in urban areas points to adverse symptoms in animals of a character similar to those suffered by man.

There are only a few reports on long-term experimental exposure of animals to sulphur oxides in which pulmonary function measurements and related physiological parameters were measured. Dogs were treated by Lewis et al (20) for 225 days with 5.1 ppm SO_2, 5.1 ppm SO_2 plus 835 micrograms/m^3 of sulphuric acid aerosol. The results of this study with far higher concentration dosages than those encountered in urban or industrial areas revealed that the exposed dogs had no significantly different values from control dogs for diffusion capacity, compliance, flow resistance or residual volume in lung function performance.

Another long-term study, reported by Vaughan et al(21), involved dogs exposed for 16 hours a day for a period of 18 months to a combination of 0.5 ppm SO_2 and 100 ug/m^3 of sulphuric acid aerosol. No impairment of pulmonary function was produced in any of the animals after 18 months of exposure. In a third long-term study reported recently by Alarie et al.(22) three groups of guinea pigs were exposed to 0.13, 1.01 and 5.72 ppm of sulphur dioxide continuously for 12 months. Pulmonary function measurements with a high degree of precision indicated that no detrimental changes could be found from this prolonged exposure to SO_2 in any of the groups of animals.

It is apparent that with regard to natural gas processing and sulphur recovery operations in Alberta and in other industrial processes involving the emission of sulphur oxides under the present government control regulations, no health hazard exists from the relatively low ground concentrations that may be found in the vicinity of such operations.

D. HUMAN HEALTH

(1) Sulphur Dioxide

Studies of the health effects of urban air pollution have been stimulated by the consequences of a series of acute air pollution espisodes that have been accompanied by increased mortality and morbidity among the exposed populations. These episodes occurred in the Meuse Valley of Belgium in 1930, Donora, Pa., in 1948, London (England) in 1952, 1956, 1957 and 1962, New York in 1953, 1963 and 1966, and in a number of large cities in Europe and Japan at other times.

Attempts to identify the agents responsible for the excess deaths and sickness in these acute episodes have not been successful. Most attention has been devoted to sulphur dioxide and particulate matter because these were the only contaminants for which concentration measurements were available at the time.

Human volunteers have been exposed for durations up to one hour by inhalation of diluted sulphur dioxide from 1 to 20 ppm and higher concentrations. Exposure to 4 to 5 ppm and higher does induce an increase in airway resistance in a majority of exposed individuals, according to studies by Frank (23, 24).

Medical personnel expose asthmatics and chronic bronchitic patients to high sulphur dioxide concentrations to determine their irritability to the inhalation. The concentrations used in these provacative tests range from 1200 to 4800 ppm in order to obtain a broncho-spasm response after a few breaths. These patients appear to tolerate these treatments without major consequences.

The theory that sulphur dioxide may condense on particles of respirable size to produce a high local concentration of gas at the site of impaction in the lungs has been proposed by Goetz (25). In tests of this hypothesis, small animals have been exposed to high concentrations of SO_2 and activated carbon dust. The gas concentrations ranged from 116 to 212 ppm. No increase in ciliary inhibition was found, other than what could be expected from the inhalation of SO_2 by itself. This absence of additive effect or of synergism appears to contradict the Goetz hypothesis.

The available data from epidemiological studies indicate that populations exposed to sulphur dioxide at significant levels of 0.5 to over 2 ppm, do not show direct evidence of increased susceptibility to respiratory infection deriving from the effects of SO_2. Major obstacles to the interpretation of epidemiological information health effects are the frequent lack of standardization of the populations that are being compared in terms of smoking, occupation and social history.

Burrows et al. (26) in a study of the relationship of symptoms of chronic bronchitis and emphysema to weather and air pollution concluded that sulphur dioxide is not specifically related to aggravation of chronic bronchitis and that air contaminants do not appear to play major roles in producing these aggravated symptoms. In a detailed study of hospitalization for diseases such as allergic disorders, acute respiratory infection, influenza and bronchitis in relation to air pollution, Sterling et al, (27) found a correlation factor of only 0.16 with sulphur dioxide, which is insignificant.

The amount of sulphur dioxide a human being can inhale and retain in serious episodes is not very great. A simple calculation will show that a man breathing sulphur dioxide steadily at 1 ppm will absorb, at most, 14 ml. of gaseous SO_2 per 24 hours. This corresponds to a weight of about 37 mg. of SO_2, which in turn represents approximately 0.57 millimole per total body weight, of either sulphur dioxide or sulphurous acid. The latter is a well known weak acid resempling kinetically carbonic acid. The net result for the organism will amount to something less than one milliequivalent of acid, an aliquot which the organism can easily dispose of. Normal kidneys, in fact, often eliminate well in excess of 20 milliequivalents per litre of urine as titratable acid. Thus, exposure to SO_2 may result in lowering urinary pH. Acid urine, in fact, has been noticed in persons exposed to high levels of sulphur dioxide in industry (28). However, these same levels, encountered in the past, in industrial exposures, are not at all comparable to those of air pollution occurrence in the outdoor atmosphere.

(2) Oxidation products of sulphur dioxide

The industrial hygiene TLV of maximum allowable concentration for sulphuric acid mist (or sulphur trioxide) has been established at 1 milligram per cubic metre of air (1 mg/m^3) for workers exposed 8 hours per day, 5 days per week. Sulphur trioxide or sulphuric acid appears to be more of an irritant than sulphur dioxide at equal doses in man and in animals. Inhaling H_2SO_4 with particle size of 0.8 micron, quinea pigs react with an increase of airway resistance when the concentration is equal or higher than 1.9 mg/m^3. Human volunteers exposed to sulphuric acid at concentrations in excess of 2.9 mg/m^3 for one hour have complained of irritation of the conjunctivae and of the respiratory mucosae. Several subjects have shown increased airway resistance,measured by the interrupter technique (29). However, exposing volunteers to 1 mg/m^3, Lawther has found no significant change in airway resistance (30). Conversely, Toyama and NaKamura, using a similar concentration of sulphuric acid, have indicated a substantial change of resistive values in exposed subjects (31).

The oxidation of sulphur dioxide to sulphur trioxide or sulphuric acid in the ambient atmosphere is a slow process, with complex equilibrium constants, as shown by Katz (32, 33). Humidity, sunlight and the presence of nitrogen dioxide as well as catalysts in the atmosphere, all have an important influence on the rate of oxidation. However, the percentages of conversion of SO_2 to sulphuric acid in the ambient atmosphere are usually in the range of 3 to 5 percent by weight, although under exceptional conditions the conversion may reach 15 to 35 percent. Measurements of sulphuric acid aerosol in polluted urban areas seldom attain levels above 0.05 to 0.10 mg/m^3. In the London smog episode of December, 1952, the concentration of sulphuric acid was estimated to reach levels not in excess of 0.35 mg/m^3. Inhalation at this concentration is well below the borderline range for measurable effects on human subjects.

It has been found that mixtures of sulphur dioxide and sulphuric acid exert synergistic effects on exposed animals but these effects occur at concentration levels that are much higher than those commonly found during air pollution episodes (Amdur, 34).

(3) Hydrogen Sulphide and Mercaptans

Hydrogen sulphide, mercaptans and related sulphur compounds may on occasion constitute an odour nuisance. Hydrogen sulphide possesses the typical smell of rotten eggs. The mercaptans have a nauseating odour. The mixture of sulphur compounds may be quite unpleasant for most people in concentrations that are in excess of odour thresholds.

E. SUMMARY

(1) Vegetation

With reference to emissions of sulphur dioxide from large sources, the major concern is the prevention of injury to native vegetation and agricultural crops. This protection can be achieved by the establishment of limits such as 0.75 ppm of sulphur dioxide for one hour, 0.50 ppm for 3 hours and 0.30 ppm for 6 hours. For a given set of environmental factors conducive to a high degree of plant susceptibility, the relation between limiting concentration and duration of exposure to SO_2 is not a simple straight line function but is an exponential relation. As the concentration is decreased, the exposure time increases exponentially until a sufficiently low concentration is attained that is non-toxic throughout the life cycle of a plant.

(2) Animal Life

In the recorded major air pollution disasters in urban areas, animals have exhibited adverse symptoms similar to those suffered by man. Controlled laboratory tests on several animal groups have indicated that no detrimental changes could be attributed to SO_2 in concentrations up to 5.5 ppm many times greater than the concentrations measured in major air pollution incidents.

(3) Human Health

Battigelli has summarized the status of available data on the health effects of sulphur dioxide as follows: "The search for an acceptable rationale or for reasonable evidence documenting a toxicological relevance of SO_2 levels, as these are encountered in urban air pollution, has thus far failed". The effect of urban air pollution on the health of exposed populations as found in acute pollution episodes and in other instances of relatively high pollutant concentrations does not appear to involve sulphur dioxide in its mechanism.

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III LEGISLATION

A. Historical Outline

  1. Canadian Regulations Prior to 1967
  2. Federal & Provincial Regulations Subsequent to 1967
  3. Pollution Control Legislation Alberta
  4. Effectiveness of Control Methods - Alberta

B. Current Regulations

C. Future Programmes

D. References

III LEGISLATION

A. HISTORICAL OUTLINE

(1) Canadian Regulations Prior to 1967

Canadian experience with the control of major air pollution problems prior to 1967 was based on regional rather than local considerations. It was customary for municipal governments to exercise control over emissions of smoke and dust from local heating and waste incineration operations, although regulation of large industrial emissions could be effectively accomplished on a regional, or provincial basis.

Beyond the provincial level in pollution control, Federal government responsibility was confined to certain aspects of a national character. It was for example, concerned with questions related to the flows of polluted air across the Canada - U.S. border. This was dealt with by the International Joint Commission established between the two countries. The Board of Transport Commissioners exercised authority under the provisions of the Canada Shipping Act in the control of smoke emission from railways or ships.

The Occupational Health Division of the Department of National Health and Welfare was the primary Federal air pollution agency. This division's activities were directed toward the provision of occupational health and air pollution advisory services, to Provincial health departments and other interested groups upon request.

The meteorological service of the Department of Transport conducted research studies on meteorological aspects of air pollution and assisted other agencies in these matters.

Other Federal agencies concerned with air pollution research included the National Research Council on the corrosive effects of air pollutants on builing materials; the Department of Mines and Technical Surveys research on combustion; and the Department of Agriculture which was concerned with the effects of air pollutants on plant and animal life.

Although air pollution control was considered a matter for public health authorities and hence a provincial problem, two provinces, namely Ontario and Saskatchewan, passed separate air pollution control acts, and Quebec drafted an act in 1968. Alberta and Manitoba had specific air pollution regulations provided under their public Health Acts, while the remaining Provinces had specific regulations except for one or more clauses of the Public Health Act in cases where a health hazard could be proven. In these provinces, the municipalities could pass bylaws for the enforcement of air pollution.

(2) Federal & Provincial Pollution Control Subsequent to 1967

Canada's entry into her second century was heralded by the cries of the "concerned citizen" and the "environmentalist. United States Senator Muskie's proclamation of Earth-Day on April 22/68, soon spread the anti-pollutionist philosophy into Canada, and the environmental protection efforts of Industry, the Scientific community and certain sections of government that had been proceeding very well but highly unnoticed by the public for years, suddenly became household topics.

Government response at both the Federal and Provincial level has been rapid, well intentioned and generally effective, in spite of the problems inherent in a somewhat archaic procedure for defining local and regional responsibilities. In addition to the Federal Air Quality Act, Clean Air Acts are presently established in Alberta, Saskatchewan, Manitoba, Ontario and Newfoundland. British Columbia has just completed a series of public hearings to develop provincial standards beyond the existing municipal control. The remaining provinces have general Environmental Protection Acts for both Air and Water quality which permit them to establish objectives and control measures.

In the haste of governments (Provincial and Federal) to react to the "Environmental Crisis", it has been difficult for industry and the individual to recognize clear terms of reference and, in some cases to identify the main controlling agency. This unfortunate situation is hardly conducive to responsible citizenship, corporately or individually, and seriously inhibits a joint attack by the public and private sector upon a common problem.

It is hoped that an interdepartmental approach with industrial input will alleviate this situation, by recognizing the needs of all departments of government to guarantee environmental integrity, as well as accepting the economic-technical aspects of industry which will insure that the multiple use concept is applied in all phases of resource development.

(3) Pollution Control Legislation in Alberta

The first legislation for the control of air pollution in Alberta was enacted in 1945 and provided a means to evaluate complaints and establish a remedy for correcting conditions where necessary. This was followed by specific legislation governing the control of dust from piles of coal and slag in 1946.

In 1955 the authority to make regulations was added, and in 1962 this was amended to include pipelines, as an item subject to control as to operations and locations. For noncompliance with the Provincial Board of Health order or with a rule or regulation for the control of air pollution, a fine could be levied, but by the terms of the Oil and Gas Conservation Act, under which all plants then operated, they were exempt from any injunction.

The first specific regulations for the control of air pollution were formulated in September of 1961. Prior to 1961, approval to construct and operate a gas plant was obtained from the Oil and Gas Conservation Board who checked with the Department of Public Health as to specific requirements before issuing a permit to construct. The main requirement was an assessment of the operators design specifications of the proposed sulphur plant incinerator stack. Subsequent to 1961, it has been necessary to obtain provisional approval from the Department of Health before the Oil and Gas Conservation Board would entertain an application to produce and process sour gas.

A basic requirement of the 1961 Department of Health regulations was the submission of plans and specifications for all new industries to the Provincial Board of Health for approval. Any pipeline or plant which was constructed prior to, or was under construction on September 15, 1961, was exempted for a period of five years after that date, with the Board of Health empowered to reduce or extend this five year period for any specific project which it deemed in the public interest to do so.

Under the 1961 regulations, the then Air Pollution Control Branch of the Dept. of Health employed the calculated value 0.2 ppm SO_2 average concentration over a 30 minute period for stack design. The operating guidelines for measured concentrations in the most critical downwind areas were as listed below.

8 hour average	0.3 ppm
1 hour average	1.0 ppm
3 minute	1.5 ppm

We would observe however, that prior to this date, and as early as 1959, these values were the basis for negotiations between individual companies and the regulatory authority.

Prior to this date, the operating companies designed their sulphur incinerator stacks on the advice of consultants and other industries, working to values as low as

0.26 ppm So_2, which even in this very early stage of the sour gas industry could match "Acceptable Standards" as presently defined by the Federal Clean Air Act objectives.

(4) Effectiveness of Control Methods - Alberta

The effect of air pollution control regulations in the Province of Alberta can be evaluated by considering the history of the gas processing industry beginning with its major expansion in the early 1950's. Until the latter years of this decade, very few sour gas processing plants existed, and the technical staffs of the two major regulatory bodies (Oil and Gas Conservation Board and Department of Public Health) were able to develop an expertise in pollution control only through the full cooperation of the operating companies.

Until 1961, design, control, and operations were essentially left up to the good judgement of the operating company, although the Provincial Board of Health still had the power to investigate a specific complaint and where necessary impose fines for violation of pollution control up to $500 per day.

A major investigation into the Pollution Potential of the Sulphur Recovery Industry was conducted by a Scientific Advisory Board in 1963. This committee reported its findings in 1964, following a year of intensive study which stated in effect, that no pollution problem existed to cause damage. This report was referenced at the meeting of the Canadian Council of Resource Ministers in 1966.

From 1961, when the first specific regulations for the control of pollution were formulated, until 1966, at which time all existing plants were required to conform with the new regulations, may be considered as a transition period to present day standards. For all plants built in this transition period of 1961 to 1966, and any existing plants which were modified or enlarged such that their processes were substantially changed, the regulations came into force on the date of commencement of construction or modification.

By 1966, all plants were operating under the latest Health Regulations and subsequently the industry has reflected a new awareness to the pollution problem. This awareness has been demonstrated throughout the major companies by the formulation of specific corporate policies in all matters relevant to pollution. The details of such policies vary from one company to another, however, there is one significant point common to all of them, and that is the acceptance of a community obligation to preserve air and water in an unpolluted form.

Some indication of the industry's success in its attempts to maintain minimal pollution levels may be seen in Figure III-1. The 1966 total sulphation rates for an eastern Canadian industrial city are presented in relation to those of a typical well managed sour gas processing and sulphur recovery plant in Alberta.

To date the Department of Environment has not established limits for total sulphation, but in other areas where limits have been established the acceptable rates are:

Residential	0.5 mgmSO_3/dm^2/day
Industrial	1.0 mgmSO_3/dm^2/day

COMPARATIVE SULPHATION RATES

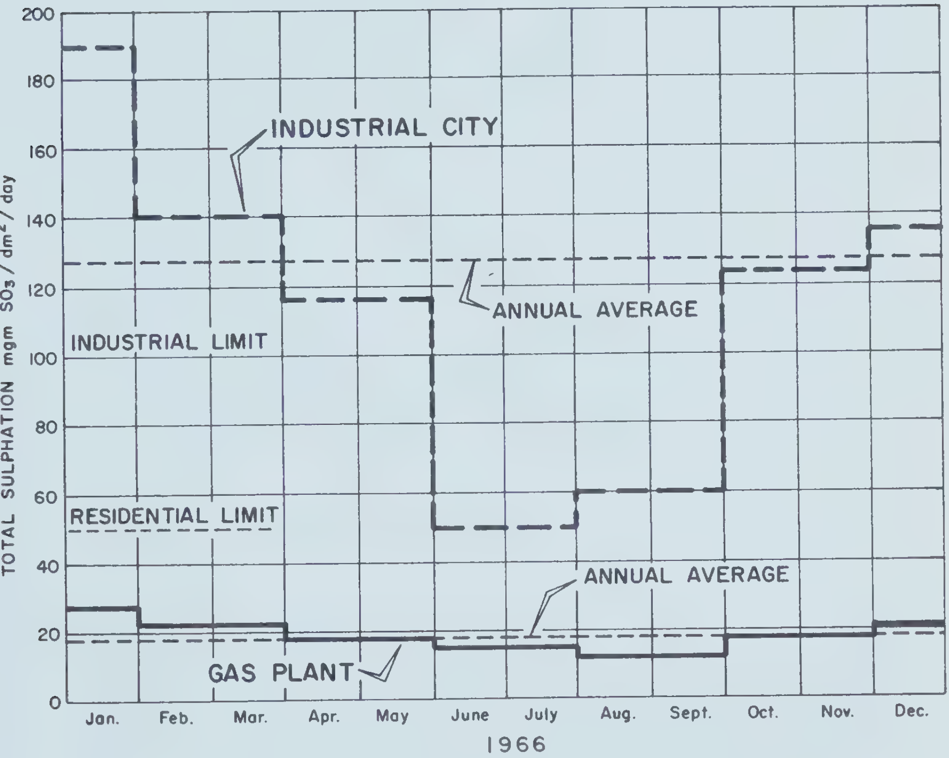

Figure III - I

In this 1966 example, the gas plant area is below the recommended residential limit of 0.50 mgm. for the entire year, while 50% of the city sulphation rates exceeded the industrial allowable. Expressed in terms of annual averages, the city value of 1.26 mgms, exceeds by a factor of 7.0 the 0.18 mgm value recorded near the gas plant.

B. CURRENT REGULATIONS

In July 1970, the Energy Resources Conservation Board (then Oil & Gas Conservation Board) was assigned further responsibilities with respect to pollution and environmental control in the oil and gas industry. The major change resulting from this announcement was that applications for the construction and operations of gas plants were submitted to a single authority, the ERC Board.

This relieved an awkward situation wherein the Dept. of Health had refused to process applications not cleared by the Board and the Board waited for Pollution approvals by the Dept. of Health. A similar untenable situation had existed in new plant applications in forested areas wherein the Dept. of Lands & Forests required a minimum clearing to provide fire protection while the local Planning Commission wanted a minimum of one section (1 mile square) in the interests of development.

A further announcement in July 1970, outlined the respective roles of the Dept. of Health and the Oil and Gas Conservation Board under four categories:

A. Areas of concern to both the Department and the Board.

B. Overall Role of the Dept. of Health
C. Overall Role of the Board
D. Details relating to pollution control at gas processing plants.

This announcement clarified the questions of standard setting, approval granting, monitoring, reporting and enforcement, but with the publication of "Minimum Sulphur Recovery Efficiency Guidelines" by the Board in November 1971, the clarification was short lived.

The industry feels that the confusion is not so much one of jurisdiction as one of discipline, viz - Environmental Protection and Resource Utilization. The industry may not be able to challenge Environmental Protection standards in terms of immediate economics, but would be well able to do so in the matter of additional recovery and storage of a commodity in considerable over supply - sulphur.

C. FUTURE PROGRAMMES

Progressively more stringent regulations may arise from more exacting air quality criteria in some countries to meet the pressures of increased industrialization. However, the Federal Air Quality Objectives appear more than adequate, and the Alberta regulations are similarily capable of protecting the populace at even the "nuisance level".

The top category - "Desirable", as defined by Federal Act is designed to long term goals of pristine air and to "provide an anti - degredation policy for unpolluted areas". The act does not define an unpolluted area, nor has any authority suggested one for this jet-age of global travel.

For more than a decade, commencing with Air Pollution courses for industry personnel by the Dept. of Health in 1960 to the 1970 drafting of reporting procedures by CPA and ERCB staffs, the industry has been able to work closely with government on this common problem of Environmental Protection Most recently, the industry has been asked to supply data to the Forestry Branch - Environment Canada to assist research studies into SO_2 effects on vegetation.

All future control programmes must be based on the results of research by the Academic, Government and Private sectors; and should not represent an over reaction to public pressure.

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IV AIR QUALITY MANAGEMENT

A. Purpose

B. Types of Air Pollution Control Standards

C. Ambient Quality Vs. Emission Standards

D. Canadian Standards

E. Provincial Standards

F. Comparative Air Quality Standards

G. Ambient Air Standards for Alberta

  (1) Present Protection

  (2) Alberta Standards in light of Others

  (3) Future Trends

H. References

IV AIR QUALITY MANAGEMENT

A. PURPOSE

The purpose of Air Quality Management is to insure that the primary use of the earth's air resource, to support life, is not compromised by the secondary uses which include the service of air as a transport medium, a constituent of production processes and receptacle for the waste residuals of all human activity.

Through effective air quality management, the assimilative and restorative capacity of the atmosphere will not be exceeded by the expanding population and industry.

Inherent in this statement of purpose by J. W. MacNeil in the constitutional study prepared for the Government of Canada entitled "Environmental Management", is the recognition of "assimilative capacity", in the atmosphere through the natural sulphur cycle.

B. TYPES OF AIR POLLUTION CONTROL STANDARDS

In general, two types of standards are employed to control air pollution in industrial and urban areas. These are emission standards and air quality standards. An emission standard establishes a limit on the quantitative rate of discharge (lbs. per hour) or concentration of a pollutant that can be emitted from a source. This emission standard limit can also be expressed in terms of the maximum permissible ground concentration at the point of impingement from the source as determined by measurement or by calculation on the basis of plume rise and diffusion theory for prevailing meteorological conditions, using specified dispersion models.

If the emission standard is expressed in terms of ground concentration limits, it can also be used as a design standard for the estimation of required stack height for a given source. In this case, the emission standard can be derived from the air quality standard.

Air quality standards are usually established on the basis of scientific criteria of cause and effect relationships between concentration level and duration of exposure to a specific pollutant of susceptible species of vegetation, animal or human health or public welfare. Other approaches to the setting of air quality standards may include the concentration levels of air quality that exist in a community on certain days of good ventilation or the conditions that existed during an earlier period when, it is believed, there were no adverse effects or the air quality conditions were tolerable by the residents of the community. Air quality standards may be adopted for an entire country or province, or different standards may be established for various areas within a jurisdiction. The "air shed" concept comprises an air quality region consisting of a geographic area which includes both the air pollution sources and the receptors within this region. Standards of air quality must be expressed in the same terms or units that are used to categorize the measurement and reporting of air quality data.

Several standards of air quality are usually employed for a major air contaminant, such as -

(1) the annual average concentration
(2) the 24-hour average concentration
(3) the maximum concentration for a short period, such as 30 minutes, one hour or several hours.

The 24-hour average concentraion may be qualified by a limit, such as, that it must not be exceeded for over one percent of the days in any 3-month or in any yearly period. Similarly, the maximum concentration and its duration may be limited, such as not to be exceeded for more than the specified time in any consecutive period of hours or days.

Both emission standards and air quality standards should be accompanied by detailed description of the method of sampling and analysis for each contaminant to be employed as a reference method. This procedure has been adopted by the U. S. Environmental Protection Agency in recent publications in the Federal Register of National Air Quality and Emission Standards.

The National Research Council of Canada established in 1971 an Associate Committee on Scientific Criteria for Environmental Quality to review available information on cause and effect relationships on receptors of contaminants in air, water, soils, and other aspects, including effects of pesticides, toxic metals and physical phenomena. The work of this Associate Committee is being conducted by a Secretariat and a number of sub-committees of experts from university, industry and government. The main objective is to provide to the Canada Department of the Environment and other governmental control agencies, properly evaluated criteria which they may use to formulate quality standards.

C. AMBIENT STANDARDS VS. EMISSION STANDARDS

As stated previously (B. - Types of Air Pollution Control Standards) the emission standard can be derived from the air quality standard at the point of impingement. It is through this procedure, with the maximum ground level concentration the independent variable, that Air Pollution Approvals have been issued for the sulphur recovery plants in the past. The ambient air quality standard protects the environment and is particularily suited to the Sour Gas Industry which is made up of isolated, essentially single point sources.

For ease of enforecement and control, Emission Standards may well be more applicable in situations of intensive, multiple sources such as domestic heating with sulphur bearing fuels, but even in this application, the emission standard should be based on an ambient air quality with computed dispersion rates for the multitude of sources.

Sour Gas Processing and Sulphur Recovery plants constitute the ultimate step in the elimination of significant groups of multiple sources, by recovering and processing the many small, and often uneconomic quantities of H_2S containing gases associated with crude oil production. Flaring operations could not be controlled by emission standards where the quantity of gas is a function of the oil production rate, and the concentration an accident of geologic history.

In the rare case of potentially merging plumes from adjacent gas plants, the ambient air quality approach can dictate some method of plant production prorationing combined with changes in dispersion through temporarily elevated stack emission temperatures to meet the existing meteorological conditions.

D. CANADIAN STANDARDS

On October 21, 1971, the Honourable Jack Davis, Minister of the Environment, announced proposed National Air Quality

Objectives for five major air pollutants: - sulphur dioxide, particulate matter, carbon monoxide, photochemical oxidants and hydrocarbons.

Mr. Davis noted that the Federal Clean Air Act was unique in that it called for three levels of air quality objectives - "desirable", "acceptable", and "tolerable" - for each major air pollutant, but his announcement concerned only the first two levels. Air quality objectives for nitrogen oxides, the sixth major air pollutant, are also under consideration and are expected to be announced shortly.

Under the Clean Air Act, the National Air Quality Objectives are designed to protect public health and welfare by setting limits on levels of pollution in the air. The maximum acceptable level corresponds in concept to the secondary air quality standards recently announced by the United States and to air quality objectives in use by some provinces in Canada. This level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being. It represents the realistic objective today for all parts of Canada. When this level is exceeded, control action by a regulatory agency is indicated.

The maximum desirable level defines the long term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology. Maximum tolerable levels, to be announced at a later date, are intended to indicate the onset of an "imminent danger" requiring immediate abatement action. Air pollution episodes which sometimes result when pollutants accumulate during adverse weather conditions would fall within this category.

The proposed air quality objectives announced were developed in consultation with provincial officials and are based on the recommendations of a Federal-Provincial Committee of experts. Mr. Davis noted that the excellent cooperation between federal and provincial authorities was an indication of the very real desire of both levels of government to come to grips with the problems of air pollution.

The proposed maximum acceptable levels and maximum desirable levels follow:

Maximum Acceptable Levels

Sulphur Dioxide

- 60 micrograms per cubic meter (0.02 ppm) annual arithmetic mean
- 300 micrograms per cubic meter (0.11 ppm) as a maximum 24-hour concentration
- 900 micrograms per cubic meter (0.34 ppm) as a maximum one-hour concentration

Particulate Matter

- 70 micrograms per cubic meter annual geometric mean
- 120 micrograms per cubic meter as a maximum 24-hour concentration

Carbon Monoxide

- 15 milligrams per cubic meter (13 ppm) as a maximum eight-hour
- 35 milligrams per cubic meter (30 ppm) as a maximum one-hour

Photochemical Oxidents

- 30 micrograms per cubic meter (0.015 ppm) annual arithmetic mean

- 50 micrograms per cubic meter (0.025 ppm) as a maximum 24-hour concentration
- 160 micrograms per cubic meter (0.08 ppm) as a maximum one-hour concentration

Hydrocarbons

- 160 micrograms per cubic meter (0.24 ppm) as a maximum three-hour concentration

Maximum Desirable Levels

Sulphur Dioxide

- 30 micrograms per cubic meter (0.01 ppm) annual arithmetic mean
- 150 micrograms per cubic meter (0.06 ppm) as a maximum 24-hour concentration
- 450 micrograms per cubic meter (0.17 ppm) as a maximum one-hour concentration

Particulate Matter

- 60 micrograms per cubic meter annual geometric mean

Carbon Monoxide

- 6 milligrams per cubic meter (5 ppm) as a maximum eight-hour concentration
- 15 milligrams per cubic meter (13 ppm) as a maximum one-hour concentration

Photochemical Oxidants

- 20 micrograms per cubic meter (0.01 ppm) annual arithmetic mean
- 30 micrograms per cubic meter (0.015 ppm) as a maximum 24-hour concentration
- 100 micrograms per cubic meter (0.05 ppm) as a maximum one-hour concentration

E. PROVINCIAL STANDARDS

At the provincial level, the most comprehensive standards are those established by Ontario and Alberta. Other provinces of Canada have not adopted such standards as yet or have only minimal requirements either at the provincial level or within metropolitan jurisdictions. The Alberta emmission and ambient air quality standards are included in the status report on the hearing. Values adopted by these two provinces for the same contaminants are comparable in general. The Ontario criteria for desirable air quality (Schedule 2) for sulphur dioxide is 0.25 ppm for one hour, 0.10 ppm average for 24 hours and 0.02 ppm average for one year. In Alberta the comparable levels are 0.30 for one hour and 0.10 for 24 hours. For hydrogen sulphide, the Ontario desirable limit is 0.02 ppm for one hour, whereas in Alberta the specified limit is 0.03 ppm for one hour and 0.005 ppm for 24 hours.

F. COMPARATIVE AIR QUALITY STANDARDS

The United States National Ambient Air Quality Standards, published in the Federal Register of April 30, 1971 for six major contaminants, are set forth in Table IV-1. The U. S. standards are of two types, primary and secondary. Primary standards are based on criteria regarding effects of the pollutants on human health, whereas the secondary standards include effects on other aspects of public welfare, i.e., social, economic, etc. In this connection, it is of interest to note that the U. S. secondary standard for sulphur dioxide permits a maximum concentration level of 0.50 ppm for 3 hours. This is much more realistic as regards effects on vegetation - a more sensitive receptor than man or animals - than the Canadian proposed federal standards or those of either Alberta or Ontario.

TABLE IV-1

U.S. Federal Ambient Air Quality Standards
(Federal Register, Vol. 36, No. 84, April 30, 1971)

	Primary Standard		Secondary Standard	
Substance	micrograms per m^3	p.p.m. (by vol.)	micrograms per m^3	p.p.m. (by vol.)
Sulphur oxides (measured as SO_2) --				
Annual arithmetic mean	80	0.03	60	0.02
Maximum 24-hr. conc.	365	0.14	260	0.10
Max. 3-hr. conc.	-	-	1,300	0.50
Particulate Matter --				
Annual geometric mean	75		60	
Maximum 24-hr. conc.	260		150	
Carbon Monoxide --				
Maximum 8-hr. conc.	10 mg/m^3	9	10 mg/m^3	9
Maximum 1-hr. conc.	40 mg/m^3	35	40 mg/m^3	35
Photochemical Oxidants --				
Maximum 1-hr. conc.	160	0.08	160	0.08
Hydrocarbons (measured as carbon and corrected for methane) --				
Max. 3-hr. conc.(6-9a.m.)	160	0.24	160	0.24
Nitrogen dioxide --				
Annual arithmetic mean	100	0.05	100	0.05

Note: Measurements of air quality are corrected to a reference temperature of 25°C and pressure of 760 Torr (1013.2 millibars). Maximum concent must not be exceeded more than once per year.

TABLE IV-2

Comparative Ambient Air Quality Standards

Substance	United States Primary	 Secondary	Canada Maximum Acceptable	 Maximum Desirable	Ontario Desirable Schedule 2
Sulphur Dioxide -	Parts per million by volume -				
Annual Arithmetic mean	0.03	0.02	0.02	0.01	0.02
Max. 24-hr. conc.	0.14	0.10	0.11	0.06	0.10
Max. 3-hr. conc.	-	0.50	-	-	
Max. 1-hr. conc.	-	-	0.34	0.17	0.25
Particulate Matter -	Micrograms per cubic meter -				
Annual geometric mean	75	60	70	60	60
Max. 24-hr. conc.	260	150	120	-	90
Carbon Monoxide -	Parts per million by volume -				
Maximum 8-hr. conc.	9	9	13	5	15
Maximum 1-hr. conc.	35	35	30	13	40
Average 24-hr. conc.	-	-	-	-	8
Photochemical Oxidants -	Parts per million by volume -				
Annual arithmetic mean	-	-	0.015	0.01	-
Max. 24-hr. conc.	-	-	0.025	0.015	0.03
Max. 1-hr. conc.	0.08	0.08	0.08	0.05	0.10
Hydrocarbons -	Parts per million by volume -				
Max. 3-hr. conc., U.S. (measured as carbon and corrected for methane)	0.24	0.24	-	-	-
Max. 3-hr. (no method specified)			0.24		

A comparison of U. S., Canada and Ontario standards for five major air pollutants is presented in Table IV-2. There are considerable discrepancies between the U. S. and Canadian standards. Those published by the U. S. Environmental Protection Agency are accompanied by a detailed description of the methods of air sampling and analysis that must be used to measure the required concentration levels of air contaminants. Such methods are a vital part of any standards because analytical methods may vary considerably as to range and sensitivity, precision, accuracy, specificity and interferences from other co-existing substances in the sample. No methods of analysis are given for the Canadian and Ontario standards. This is a serious omission.

Standards proposed for Canada are unrealistic as to potential effects on receptors. Levels for SO_2 and particulate matter are much too low. The annual and 24-hour maximum levels for photochemical oxidants are equivalent to or less than the natural background concentrations of ozone or oxidents prevailing in rural areas due to electrical discharges or diffusion to the lower atmosphere from the stratosphere.

Annual geometric means for particulate matter can be exceeded by natural background contamination from windblown soil, vegetation and other particles such as pollen, spores, etc. Hydrocarbons emitted from forests in combination with natural evolution of oxides of nitrogen will yield higher concentrations of photochemical oxidants than those given in the Canadian standards for annual and 24-hour means.

A maximum SO_2 level of 0.50 ppm for 3 hours (U. S. Standard) is much more appropriate than the Canadian one-hour level. None of the standards for particulate matter specifies the particle size range or chemical nature of the material. It is well known that the respirable range excludes particles larger than 7.5 microns in diameter. The usual method of sampling for particulates involves collection of a 24-hour sample by filtration of a measured volume of air. This collects material ranging from sub-micron size to "rocks" of 40 to 100 micron diameter. Mass concentrations without particle size distribution and chemical composition is meaningless as to potential effects on receptors.

The State of California was the first government jurisdiction to adopt ambient air quality standards in North America (State of California, Department of Public Health, 1959 and 1962). Their published Air Quality Standards with Footnotes are presented in Table IV-3. The "adverse level" for sulphur dioxide at 1.0 ppm for 1 hour and 0.30 ppm for 8 hours, on the basis of plant damage, is still the most realistic standard in relation to known criteria for the most susceptible species of vegetation. It is probable that the California limits of air quality will be superseded by the U. S. Federal standards.

Limits of allowable concentrations of atmospheric pollutants established by the U. S. S. R. are presented in Table IV-4. Two limits have been adopted for each pollutant; a single maximum concentration, usually for a duration of about 20 minutes, and a 24-hour average concentration, in units of milligrams per m^3 of air. For SO_2 the maximum concentration in ppm by volume is only 0.19 and the 24-hour average, 0.057 ppm (at $25^{\circ}C$ and 760 Torr). For hydrogen sulphide, the maximum level is equivalent to 0.02 ppm and the 24-hour average to 0.007 ppm. In general, the Russian limits are lower than those of any other nation in the world. However, a review of actual air quality data in Russian cities and industrial areas indicates that their standards have not

TABLE IV-3

State of California Standards for Ambient Air Quality

POLLUTANT	"ADVERSE" LEVEL Level at which there will be sensory irritation, damage to vegetation, reduction in visibility or similar effects.	"SERIOUS" LEVEL Level at which there will be alteration of bodily function or which is likely to lead to chronic disease.	"EMERGENCY" LEVEL Level at which it is likely that acute sickness or death in sensitive groups of persons will occur.
Oxidant	"Oxidant Index" 0.15 ppm for 1 hr by the potassium iodide method (eye irritation, plant damage and visibility reduction)	Not applicable	Not applicable
Ozone		Footnote 1	Footnote 2
Nitrogen Dioxide		Footnote 3	Footnote 3
Hydrocarbons		Footnote 4	Footnote 4
Photochemical Aerosols		Not applicable	Not applicable
Carcinogens	Not applicable	Footnote 5	Not applicable
Sulphur Dioxide	1 ppm for 1 hr or 0.3 ppm for 8 hrs (plant damage)	5 ppm for 1 hr (bronschoconstriction in human subjects)	10 ppm for 1 hr (severe distress in human subjects)
Sulphuric Acid	Footnote 6	Footnote 6	Footnote 7
Carbon Monoxide	Not applicable	30 ppm for 8 hrs or 120 ppm for 1 hr (interference with oxygen transport by blood)	Footnote 8
Lead	Not applicable	Footnote 9	Footnote 9
Ethylene	Footnote 10 0.5 ppm for 1 hr or 0.1 ppm for 8 hrs (damage to vegetation)	Not applicable	Not applicable
Particulates	Sufficient to reduce visibility to less than 3 miles when relative humidity is less than 70%	Not applicable	Not applicable
Hydrogen Sulphide	0.1 ppm for 1 hr (sensory irritation)	5 ppm may interfere with appetite in sensitive groups	50-100 ppm for 1 hr may cause conjunctivitis and and irritation
Hydrogen Fluoride	Footnote 11	Footnote 11	Not applicable

Footnotes to Table 3

1. **Ozone**, at 1 ppm for 8 hrs daily for about a year, has produced bronchiolitis and fibrositis in rodents (Stokinger, H.E., Wagner, W.D., and Dobrogorski, O.J. A.M.A. Archives of Industrial Health, 16:514,

FOOTNOTES TO TABLE IV-3 (Continued..)

1957). Extrapolation of these data to man is difficult. Functional impairment data have been reported by Clamann and Bancroft (Clamann, H.G., and Bancroft, R.W. Advances in Chemistry, No. 21, pp. 352-359, 1959); at 1.25 ppm some effect is observed on residual volume and diffusing capacity. The variability of the tests was not reported. Additional data would be needed before a standard is set.

. A value of 2.0 ppm of ozone for 1 hr may produce serious interference with function in healthy persons, and the assumption is made that this might cause acute illness in sensitive persons. (Clamann, H.G., op. cit.).

. Five ppm of nitrogen dioxide for 8 hrs will produce decreased pulmonary function in animals. Slightly more may produce pulmonary fibrosis (Stokinger, personal communication); nitrogen dioxide from air pollution exposures is usually combined with nitric oxide and ozone. More data on human exposures will be needed prior to setting a standard.

. Hydrocarbons are a group of substances most of which, normally, are toxic only at concentrations in the order of several hundred parts per million. However, a number of hydrocarbons can react photochemically at very low concentrations to produce irritating and toxic substances. Because of the large number of hydrocarbons involved, the complexity of the photochemical reactions, and the reactivity of other compounds such as nitrogen dioxide and ozone, it is not yet possible to establish "serious" and "emergency" levels for hydrocarbons. From the public health standpoint, the concentration of those hydrocarbons which react photochemically should be maintained at or below the level associated with the oxidant index defined in the "adverse" standard.

5. Carcinogens include a few organic compounds such as some polycyclic hydrocarbons, and some metals such as arsenic and chromium. Studies on effects of such substances are currently under way, but there are not sufficient data, at present, to set standards. In the meantime, it is recommended that concentrations of carcinogens in air should be kept as low as possible.

6. A sulphuric acid mist level of 1 mg/m^3 with an average particle size of one micron will produce a respiratory response in man. (Amdur, M.O., Silverman, L., and Drinker, P. Archives of Industrial Hygiene and Occupational Medicine, 6:305, 1952). It is not possible to generalize from this for all air pollution conditions, because under natural conditions, particle size will vary. Only with large droplets would sensory irritation be produced without other physiological effects.

7. A level of 5 mg/m^3 of sulphuric acid mist for a few minutes produces coughing and irritation in normal individuals (Amdur, M.O., Silverman, L., and Drinker, P. op. cit.). Presumably, it could cause acute illness in sensitive groups of persons in a period of 1 hr.

8. Given certain assumptions concerning ventilatory rates, acute sickness might result from a carbon monoxide level of 240 ppm for 1 hr in sensitive groups because of inactivation of 10% of the body's hemoglobin. In any event it is clear that when a population exposure limit has been set for carbon monoxide, because of exposures from other sources, community air pollution standards should be based on some fraction of this limit.

9. It is clear that lead levels should be set on the basis of average values for long periods. While data are abundant concerning human response to eight-hours-a-day, five-days-a-week exposure, data are insufficient for the effects of the continuous exposure inherent in community air pollution. While laboratory studies will be pursued with vigor, it becomes very important that local agencies collect data on existing lead levels. Since lead exposures are from multiple sources, community air pollution standards should be based on a portion of the total limit for population exposure.

0. Ethylene causes severe damage to vegetation. Ornamental plants are severely injured by exposures from 0.2 to 0.5 ppm. Tomatoes and fruit are adversely affected at similar levels.

1. Hydrogen fluoride and other airborne fluorides settle upon and some are absorbed into vegetation. When forage crops containing 30-50 ppm of fluoride measured on a dry weight basis are regularly consumed over a long period, the teeth and bones of cattle may show changes, depending upon age, nutritional factors and the form of fluoride ingested. Such changes may or may not have any economic effect. Fluorides at these levels do not necessarily cause injury to the forage plants themselves. The irritating properties of hydrogen fluoride in experimental human exposure have been manifested by desquamation of the skin, at concentrations of 2-5 ppm. Mucous membrane irritation also occurs from hydrogen fluorides but quantitative data are not adequate to support a standard.

TABLE IV-4

Russian (U.S.S.R.) Limits of Allowable Concentrations of Atmospheric Pollutants

	Limits of allowable concentrations in mg/m^3	
	single maximum	average daily (24 hrs)
Sulphuric acid aerosol	0.30	0.10
Sulphur dioxide	0.50	0.15
Hydrogen sulphide	0.030	0.010
Hydrogen sulphide in combination with petroleum gas	0.015	0.005
Phenol	0.30	0.10
Benzene	2.4	0.8
Fluorine compounds	0.03	0.01
Carbon monoxide	6.0	1.0
Hydrogen chloride	0.05	0.015
Dust (non toxic)	0.50	0.15
Fluorine and its compounds (as .F)	0.03	0.01
Nitrogen oxides	0.30	0.10
Chlorine	0.10	0.03
Lead	-	0.0007

been implemented as yet.

A number of West German air quality standards is given in Table IV-5. In the case of sulphur dioxide, a peak level of 0.30 ppm is the maximum permissible concentration for three half-hour periods daily in excess over a steady value of 0.15 ppm. Under similar terms, the corresponding peak value for hydrogen sulphide is 0.20 ppm and the steady value 0.10 ppm.

Japan has adopted an air quality standard for sulphur dioxide of 0.20 ppm for 3 hours. In the Netherlands, the SO_2 standard varies over the average range for 24 hours from 0.05 to 0.18 ppm, depending upon the nature of the area in relation to concentration of industry and population.

An excellent review of air pollution standards that covers the practice in many countries of the world has been presented by A. C. Stern in Chapter 51 of Volume III of "Air Pollution", Second Edition, Academic Press, 1968. In Canada, the Associate Committee of the National Research Council has not accepted the conclusions reached in the Air Quality Criteria Documents published by the National Air Pollution Control Office of the United States (EPA), believing that many of the findings reported in the literature by scientific investigators have not been properly interpreted. It is believed that more accurate criteria on which to base standards will become available to Canada as a result of these NRC studies.

G. AMBIENT AIR STANDARDS FOR ALBERTA

(1) Present Protection

In Section II, an effort was made to indicate the limits

TABLE IV-5

West German Air Quality Standards

(VDI - Kommission Reinholtang der Luft)

	Maximum permissible concentration	
	Steady Value (as half-hour average)	Peak Value[a] (as half-hour average)[b]
	ppm	ppm
Sulphur Dioxide	0.15	0.30
Oxides of Nitrogen	0.5	1.0
Chlorine	0.1	0.5
Hydrogen Sulphide	0.1	0.2

(a) Permissible excess over steady value.

(b) Not to be exceeded more than three half-hour periods daily.

of SO_2 and H_2S that can be tolerated by the environment. Now let us examine the limits as set by the Alberta Department of the Environment on these compounds. Table IV-6 gives the Alberta Ambient Air Quality Standards for SO_2, H_2S, and several other pollutants. The one hour average concentrations limit for SO_2 is 0.30 ppm and for H_2s it is 0.030 ppm. In the case of SO_2 previous discussion showed that a concentration of 0.30 ppm presented no detrimental effects on the most sensitive plants, when exposed to such concentrations for four hours per day for a month. Thus the limit of 0.30 ppm for one hour for SO_2 is more than adequate to protect vegetation, animals and humans. Similarly the limit for H_2S is well below any concentrations that would harm the vegetation or humans. The twenty-four hour limits of 0.10 ppm and 0.005 ppm respectively for SO_2 and H_2S currently in effect in Alberta are also well below those that studies shows would cause adverse effects.

The Ambient Air Quality Standards published by the Department of the Environment in Alberta are designed to "protect the health and welfare of all citizens and maintain the quality of the Province's air resource and prevent insofar as possible, deleterious effects to animals, plants and property".

Further to the Ambient Air Quality Standards, the Report has provided a schedule of "Maximum Calculated Ground-level Concentration Standards". A comparison of these standards, together with those recommended under the Federal Governments Clean Air Act are shown in Table IV-7. Significantly, the Federal (Canada) and Alberta standards include "welfare" as their objectives, which implies that both damage and nuisance levels have been fully considered. Further the "welfare" objective provides a safety factor beyond the critical levels for plant damage.

TABLE IV-6

AMBIENT AIR QUALITY STANDARDS

	POLLUTANT	CONCENTRATION UNIT	AVERAGE CONCENTRATION FOR APPLICABLE TIME PERIOD			METHOD OF MEASUREMENT
			1 HR.	24 HR.		
1	FLUORIDES (as HF)	ppm. (vol.)		.0040		Spectrophotometry
		mg./m^3		.0033		
	FLUORIDES in forage for livestock (dry wt. as F)	ppm. (wt.)			35.0	Gravimetry
		mg./1			35.0	
2	TOTAL OXIDANTS (as O_3)	ppm. (vol.)	.15	.10	90% of readings per month < .07 ppm. (vol.) (.137 mg./m^3)	Spectrophotometry
		mg./m^3	.29	.20		
3	TOTAL OXIDES OF NITROGEN (as NO_2)	ppm. (vol.)	.30	.10		Spectrophotometry
		mg./m^3	.56	.19		
4	CARBON MONOXIDE (CO)	ppm. (vol.)	60.0		8 hour average 15.0 ppm. (vol.) (17.2 mg./m^3)	Infrared Spectrophotometry
		mg./m^3	68.7			
5	HYDROGEN SULFIDE (H_2S)	ppm. (vol.)	.030	.005		Light transmittance or reflectance
		mg./m^3	.042	.007		
6	SULFUR DIOXIDE (SO_2)	ppm. (vol.)	.30	.10		Conductivity
		mg./m^3	.79	.26		
7	SOILING INDEX	coh	90% of average readings per month < 1.0		Annual Average < .45	Light transmittance or reflectance

TABLE IV-7

SULPHUR DIOXIDE (PPM)

	FEDERAL AIR QUALITY OBJECTIVES	ALBERTA AMBIENT STANDARDS (MEASURED)	ALBERTA DESIGN (CALCULATED)
(a) TOLERABLE			
(b) ACCEPTABLE			
1/2 hour	----		0.2
1 hour	0.34	0.30	
24 hours	0.11	0.10	
Annual	0.02		
(c) DESIRABLE			
1 hour	0.17		
24 hours	0.06		
Annual	0.01		

The "Maximum calculated groundlevel concentration standards" provide adequate safe design criteria, for sulphur plant stack heights. Summarily, the Alberta standards allow for two orders of safety beyond the levels where plant damage could occur. The absence of SO_2 vegetation damage downwind of gas plants in Alberta verifies the cautious approach used by the authorities to date in granting approvals.

(2) Alberta Standards in Light of Others

Ambient Air Quality Standards established by various Government agencies in the United States and Canada are listed in Table IV-8.

It can be noted that there are considerable discrepancies between the Canadian proposed objectives and the U. S. standards. A maximum acceptable limit of 0.34 for one hour is unrealistic in terms of known criteria for sulphur dioxide effects on sensitive plant species. This type of exposure is harmless and very much below the exposure threshold for minimum leaf injury. The U. S. (EPA) secondary standard of 0.50 ppm for 3 hours (26) is one that relates to effects on public welfare (including vegetation), comparable to the Canadian definition of a "desirable" level. It is a much more realistic limit for protection of plant life. In Alberta, the SO_2 standard is set at 0.30 ppm for one hour and 0.10 for 24 hours.

Maximum 24-hour concentrations at all the levels indicated above are meaningless regarding vegetation, unless they include several hours of peaks greater than 0.50 ppm. On the basis of both experimental studies and field experience, 24-hour exposures in the range of 0.14

TABLE IV-8

Comparative Ambient Air Quality Standards for Sulphur Dioxide

Maximum Exposure Limit	State of California	U. S. Environmental Protection Agency		Canada		Ontario	Alberta
	Adverse level ppm	Primary ppm	Secondary ppm	Max. Acceptable ppm	Max. Desirable ppm	Desirable Schedule 2 ppm	
One hour	1.0	--	--	0.34	0.17	0.25	0.30
3 hours	--	--	0.50	--	--	--	--
8 hours	0.30	--	--	--	--	--	--
24 hours	--	0.14	0.10	0.11	0.06	0.10	0.10
Annual Arithmetic mean	--	0.03	0.02	0.02	0.01	0.02	--

to 0.10 ppm are very much below threshold limits, since normal crop plants can be grown in a continuous atmosphere at such levels.

With reference to emissions of sulphur dioxide from large sources, the major concern is the prevention of injury to native vegetation and agricultural crops. This protection can be achieved by the establishment of limits such as 0.75 ppm of sulphur dioxide for one hour, 0.50 ppm for 3 hours and 0.30 ppm for 6 hours. For a given set of environmental factors conducive to a high degree of plant susceptibility, the relation between limiting concentration and duration of exposure to SO_2 is not a simple straight line function but is an exponential relation. As the concentration is decreased, the exposure time increases exponentially until a sufficiently low concentration is attained that is non-toxic throughout the life cycle of a plant.

(3) Future Trends

The problems with H_2S and SO_2 around sour gas operations can be classified into two categories: as potentially harmful to growth and health, or as a nuisance due to bad odours. It was shown that the Alberta Ambient Air Quality Standards currently in effect are already more than adequate to protect the health of vegetation, animals and humans. The main source of SO_2 is the sulphur plant stack. Reducing SO_2 emissions from this source will have no bearing on the other problem, namely, odours around sour gas operations. As mentioned, the odours are due to hydrogen sulphide and mercaptans, and none of these compounds originate from the sulphur plant stack. Thus enforcing a more stringent standard with regard to SO_2 will have no bearing on the problem of odours, as the threshold odour concentration of

SO_2 is 0.47 ppm, which is higher than the one hour SO_2 limit of 0.30 ppm. Since the current Alberta Ambient Air Quality Standards are already more than adequate for the protection of the environment, a further restriction would be analogous to imposing a 30 m.p.h. speed limit on the No. 2 highway between Calgary and Edmonton, in order to improve traffic safety.

In Alberta, the Department of the Environment sets the Ambient Air Quality Standards, and the Energy Resources Conservation Board monitors and enforces these standards. However, under current practice, the Board has superimposed its own SO_2 ground level concentration, which are in many cases more stringent than the Air Quality Standards. It is strongly felt by industry that the approach to this overall problem of ambient air quality should be through the Department of the Environment setting the Ambient Air Quality Standards, and this should be sole criterion for monitoring the performance of sulphur plants. Thus the performance of the sulphur plant operation should be judged on the SO_2 content of the surrounding air. The present system of two agencies of the government setting different regulations on SO_2 levels is not a desirable situation for the operation of sulphur plants.

V STACK DESIGN

A. Predicted Ground Level Concentration

B. Analytical Models

C. Numerical Models

D. Variability of Plume Rise Estimates

E. References

V STACK DESIGN

A. PREDICTED GROUND LEVEL CONCENTRATION

Sulphur plant waste gases are emitted to the atmosphere through incinerator stacks designed for maximum ground level concentrations of sulphur dioxide to be within the half-hour concentration standard applicable to the area. The design calculation principles currently utilized by the Energy Resources Conservation Board are the analytical type models of Sutton and Pasquill (Dept. Health Handbook)(1). Industry experience indicates that stacks designed by these methods provide more than adequate environmental protection at ground level by virtue of measured SO_2 ground level concentrations being less than ambient air standards 99% of the time(2). It is also recognized that other factors affecting low ground level concentrations could be plant gas throughput volumes less than design maximums and because stack design criteria of critical atmospheric wind speed is experienced only a minor portion of the time. Incidents of ground level concentrations exceeding standards do occur on occasion because of topographical or meteorological phenomena. The Topographical exceptions may be precluded in future with improved air quality modelling techniques while the meteorological exceptions, because of unpredictable intensity and occurrence, currently are regarded as impractical to prevent. Despite these phenomena it is contended there is no conclusive evidence of vegetation or animal damage in this province resulting from sulphur plant stack emissions. Concern in the past over "nuisance" odors are believed primarily to have resulted from problems in field well operations. These operations have been materially improved during recent years with an accompanying reduction of field area resident complaints.

The CPA agrees with the statement of the ECA Situation Report that while, "the formula used to establish a proper stack height for a pollution emission rate have a certain amount of physical justification, they are basically just useful approximations". However recognition must be given to the predicament of obtaining more data and utilizing involved techniques at considerable cost for those cases where there is only a marginal improvement in prediction capability. The present Sutton and Pasquill methods have been found to be appropriate generally for level terrain conditions but may provide erroneous predictions for significant topographic features. Undoubtedly as technology develops in this area it will be applied by industry and accepted by regulatory bodies.

B. ANALYTICAL MODELS

Bibbero (3) States "...the primary question asked of a mathematical model (is): "What will be the pollutant concentrations at any point in the air quality region, given all the data on sources and meteorological conditions. In theory, a complete answer to this question can be given only be continuously tracking the pollutants emitted from individual sources and computing the concentration of each species at every point as they are transported by wind, spread by diffusion, mixed by turbulence, and reflected or channeled by surfaces such as ground or valleys. The basic consideration of mass continuity in fluid dynamics leads to complex vector equations that describe the time varying changes in the concentration field. The problem is much like that of trying to describe the changing intensity of a soluble dye at every point after it is dropped into a swirling, turbulent brook, except that (in air quality modelling) we must also account for the chemical decay of each species with time and their reactions to each other."

The equation basic to modelling(4) after a number of simplifications which neglect the small rates of molecular diffusion as compared with the much greater turbulent eddy diffusion (E) coefficients, results in an expression of the following form:

$$\frac{\partial C}{\partial t} + \bar{U} \cdot \nabla C = \nabla \cdot E \nabla C + q + q_{ga} + R \qquad (1)$$

Where:

C	Pollutant concentration
E	Eddy diffusivity with components Ex, Ey and Ez in the x, y and z directions, respectively
t	time
R	Rate of disappearance of pollutant due to reaction
$\bar{U}$	Time averaged air velocity vector consisting of vectors u, v and w in the x, y and z directions, respectively
q.	pollutant source rate
q_{ga}	Pollutant ground adsorption rate

This equation assumes that the air density does not change with space or time.

The exact solution of (1) is difficult to implement because of the serious problems in defining the diffusion coefficients E, and the non linear nature of the chemical reaction term R. The diffusion coefficient E is a function of the size and the velocities of the turbulent eddies which in turn depend on many factors and interactions and as a result become very complicated functions of their positions in the field.

If the chemical reaction and ground adsorption terms are ignored and the magnitude of the diffusion coefficients is considered known (may be determined from the field data), then the exact solution for the steady state version of equation (1) can be obtained. The wind velocity and diffusivity may be either assumed constant or allowed to vary as a known power law function.

Sutton$^{(5)}$ solves for pollutant concentration considering height dependent diffusivity and velocity and concludes that use of velocity given by one-seventh power law and eddy diffusivity given by six-sevenths power law, gives ground concentrations in good agreement with observations of smoke dissipation from a continuous line source.

Rather than employing a purely analytical solution, useful attempts (such as one due to Pasquill$^{(6)}$) have been made to utilize the statistical properties of turbulence. The most popular scheme is to assume that the plume on a single species of effluent (neglecting any chemical reaction) from each source spreads out randomly as it is blown downwind (Gaussian Plume Model). Thus, the pollutant concentration along any axis across the plume's cross section is distributed according to the familiar Gaussian or bell shaped curve (see Figure V-1). A continuous point source is located at x=y=z=0. Dispersion in the x-direction downwind of stack (or source) is ignored and the mean wind speed is assumed constant in time.

The pollutant concentration at any point is then given the following relationship for wind in the x-direction:

$$C = \frac{q}{2\pi\sigma_y\sigma_z u} e^{\left(\frac{y^2}{2\sigma_y^2} + \frac{z^2}{2\sigma_z^2}\right)}$$

CO-ORDINATE SYSTEM SHOWING GAUSSIAN DISTRIBUTION
IN HORIZONTAL AND VERTICAL DIRECTION

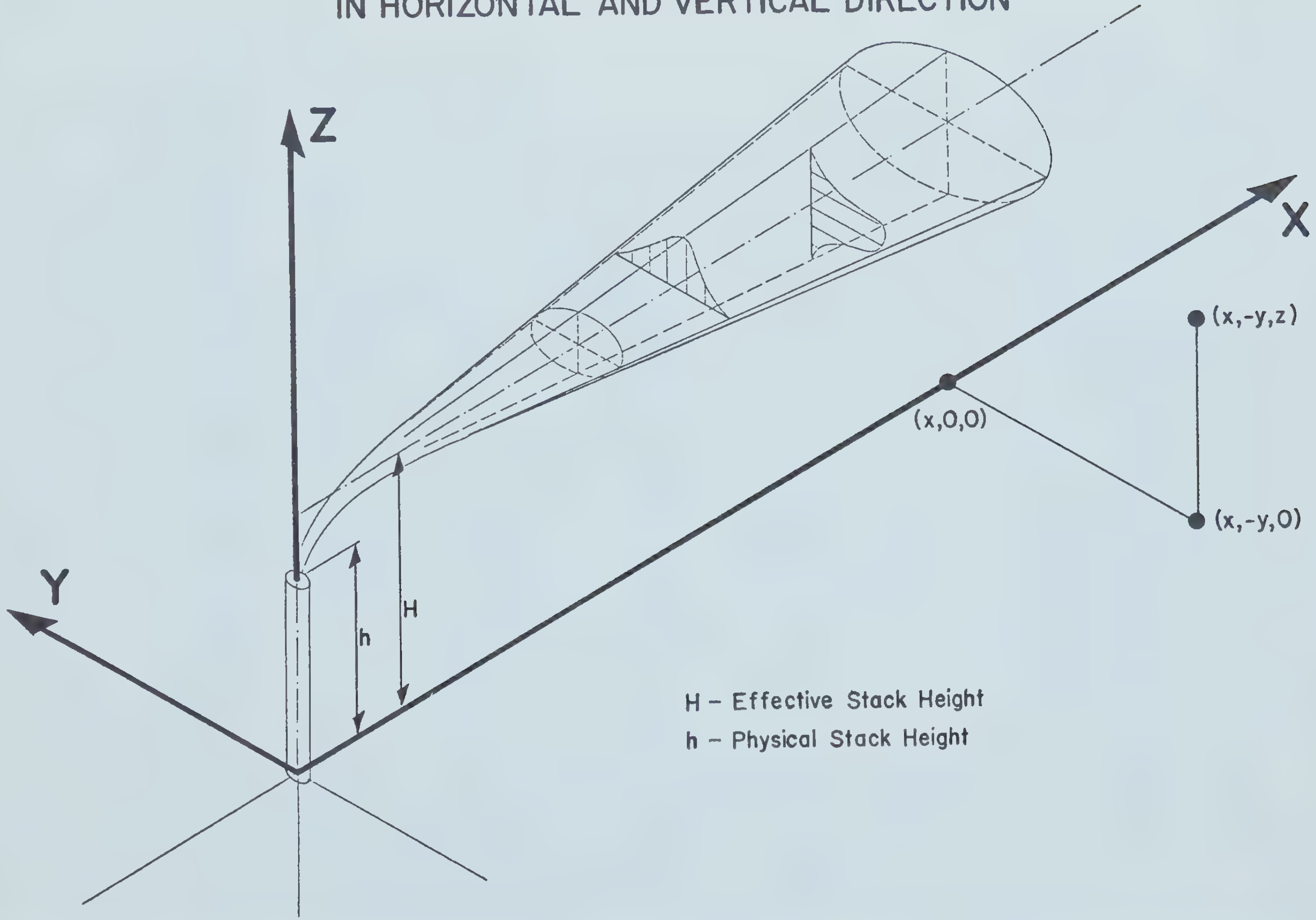


Figure V

Where:

σ_y	Standard deviation of horizontal gas concentration distribution in plume
σ_z	Standard deviation of vertical gas concentration distribution in plume
y	Lateral distance from vertical plane through the stack (or source) and parallel to mean wind direction.
z	Height above ground

and other symbols are the same as previously presented.

It is noted that the previous problem of determining the diffusion coefficients E has been offset by a similar problem in the Gaussian plume model of evaluating new statistical variables σ_y and σ_z. A number of field studies however, have been conducted resulting in expressions capable of defining the standard deviations in terms of diffusion parameters. The diffusion parameters in turn depend on stability, mixing depth as well as the gustiness of the wind. These factors, of course, vary with terrain. Although rather extensive evaluation has been conducted in Brookhaven National Laboratories where the ground is flat and wooded and in the rolling country of Porten, England, the terminology used to describe stability and the numerical values obtained have not been in perfect agreement(7). Thus there is still a problem in finding the correct numbers to put into diffusion equation.

Despite the difficulties of finding appropriate diffusivity parameters the analytical models have been used extensively to locate and design stacks for industrial plants. They have been routinely used by the Alberta Energy Resources

Conservation Board and prior to that by the Department of Health to determine the average distribution of pollutants around gas plants. Their popularity stems from the fact that these models are inexpensive and easy to use. At the same time they provide reasonable answers for cases involving flat topography and simple meteorological conditions.

A number of field tests of analytical models(8)(9) are reported in the literature. Generally, the resolution of the models appears to be a kilometer or more in space and from two hours to a month in time. Perhaps the most extensive tests of Gaussian Plume models have been conducted by Miller and Holzworth(10) in three different cities. These authors were able to report 90 percent of two hour averages correctly within .01 ppm.

Considering the coarseness of the input data, the model results are acceptable. Nevertheless, they are severely limited by their inability to account for the time variation of source strengths, and their limitation to single sources and inert contaminants. Their most severe limitation for routine use for gas plants lies in their inability to account for uneven terrain and unusual meteorological conditions such as fumigation.

C. NUMERICAL MODELS

The limitations of the analytical solutions of the diffusivity equation lead to the development of more ambitious models which solve some form of the diffusivity equation numerically, usually employing computers.

The approach generally has been first to numerically solve the equations expressing conservation of momentum of the wind field to account for its modification due to topographical effects or large urban buildings. The velocity distribution thus obtained at each grid point is used in the numerical solution of the convection-diffusion equation (1). The diffusion coefficients for a given geographical area for the numerical models are normally obtained by history matching the existing concentrations. Several recent publications have described methods which can include topographical effect (11)(12)(13) or large urban buildings(14)(15).

Lantz(13) et. al. use a modified form of the three-dimensional equation for velocity potential. The modification includes 1) inviscid potential flow at high elevation, and 2) height dependent coefficients which account for surface friction in the boundary layer. This emperical modification causes the horizontal velocities to vary with height. This formation of the convection-diffusion equation also includes the terms defining first order chemical reaction (with no interaction of components) and an approximate ground adsorption term. Calculated results from the numerical models are in good agreement with Gaussian Plume models for simple level terrain cases, but for complicated terrain cases numerical model results are different and appear to be more accurate than the plume models.

The state of the art of numerical modelling does not permit yet the theoretical calculation of diffusion constants, however, it does provide for the standardization of the model for a given geographical area and meteorological event by history matching the observed ground level concentrations. The diffusion constants determined in this fashion can then be used confidently to extrapolate the results to account for additional sources and background concentrations, different wind velocities, or change in plant operations. In addition, these models allow the diffusivities and the wind velocity to become arbitrary functions of space and time. This means that certain meteorological phenomena like the mountain and valley winds, or the land and lake breeze can be adequately accounted for. Numerical modelling allows for transient concentration calculations which enables one to compute concentrations during fumigations and well flaring.

An important advantage of numerical models is that they allow the consideration of the effect of topography on modifying wind field. The problem is illustrated in Figure V-2. The length of the arrows in this figure represents the magnitude of the wind velocity. In the plume models it is assumed that the hill acts as a "sieve" and thus the wind field remains unaltered. With the numerical model, the highest pollutant concentration over a hill may be as much as an order of magnitude(13) lower than the plume model due to recognition of the change in the vertical wind direction.

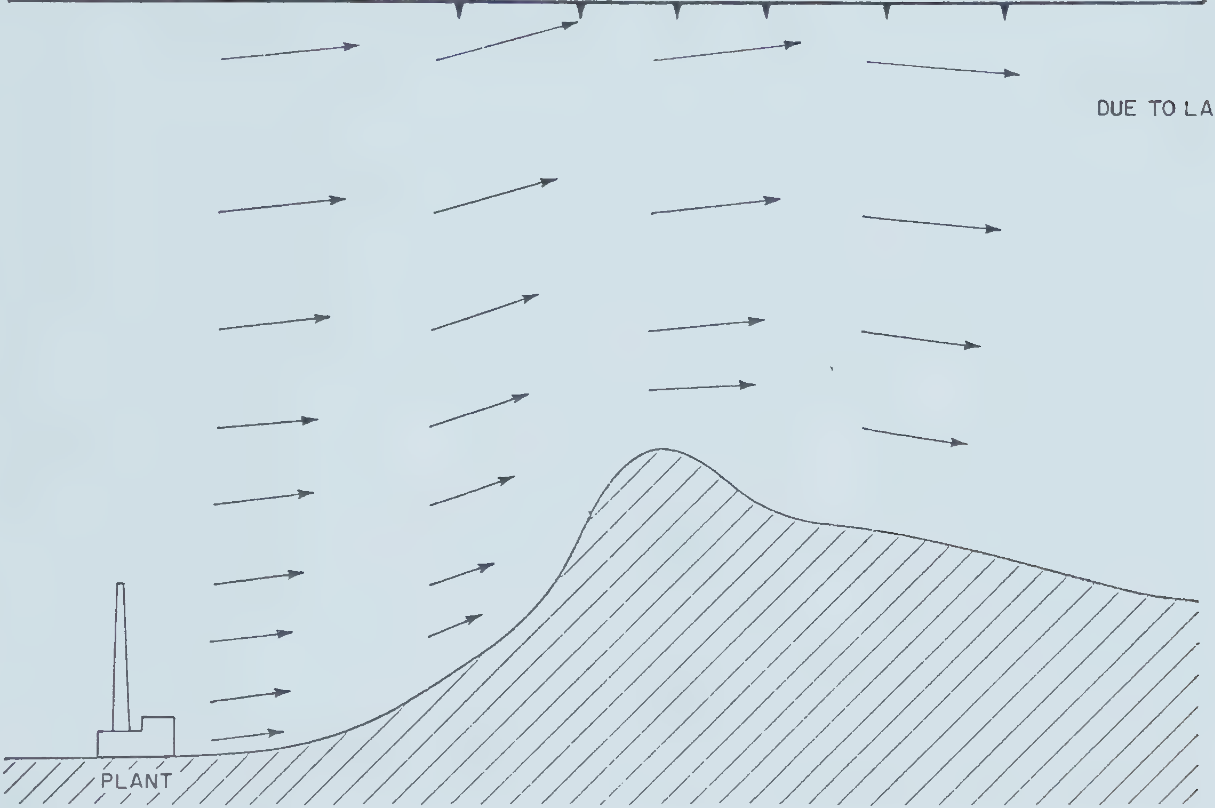
D. VARIABILITY OF PLUME RISE ESTIMATES

Under most predictive modelling situations, the value of effective stack height is an influential parameter for ultimate stack design. Effective stack height is the effective emission level of the plume relative to the ground having regard to thermal and momentum rise of the stack effluent as well as the actual stack height.

The rise of a plume of waste gas from a stack depends

GROUND LEVEL SO_2 CONCENTRATIONS, ppm

NUMERICAL MODEL	.04	.24	.12	.11	.10	.10
PLUME MODEL	.12	2.4	2.3	1.4	1.5	1.3



DUE TO LANTZ et al

CROSS SECTION OF WIND VELOCITIES FOR NEUTRAL STABILITY

Figure V-2

upon a considerable number of factors that include stack parameters and variable meteorological conditions. The most important stack parameters are the momentum and buoyancy (or heat emissions rate) of the waste stack gas while meteorological variables include wind speed, air temperature or density and conditions of atmospheric stability. Plume rises for a given set of stack operating parameters also will vary over a wide range under different degrees of atmospheric stability such as unstable, neutral and stable or inversion conditions.

Atmospheric conditions that produce changes in turbulence would affect the rates of dissipation of momentum and heat content of a plume and the resultant height to which it will rise. During period of strong directional wind shear, much lower plume rises would occur as a result of more effective mixing in the atmosphere, reduction in buoyancy and increase in surface area of the plume. Topographical features of the terrain, such as variations in elevation of the surrounding area and heights of buildings at the plant site, also exert a considerable influence on plume rise.

Many plume rise models and formulae have been proposed by various authors to calculate the rise of gas plume for small, medium and large process units or power plants. The analysis of sulphur plant plumes, wherein thermal parameters in particular and momentum parameters are significantly different from these power plant data, is presently under review. A recent analysis of the data on observed versus calculated plume rises from power stacks by seventeen different formulae has been made by Moses and Kraimer(16). This investigation was based on 615 measurements arising from ten different plume rise research programmes using 26 different stacks. For the 615 cases, the mean ratios of observed to calculated plume rise values from the 17 formulae varied from a low of 0.27 (overestimation of calculated values) to a high of 7.8 (under-estimated).

A summary of the comparative data obtained in the study of Moses and Kraimer is presented in Table V-1.

TABLE V-1

Mean Ratios of Observed to Calculated Plume Rise Values

Moses & Kraimer

Stack Height Range	no. of Observations	Concawe (17)	Lucas, Moore & Spurr (18)	Moses & Carson (19)	Briggs (20)	Holland (21)
Small Stacks	166	1.50	0.16	2.10	0.92	5.33
Intermediate	352	0.69	0.28	1.06	0.84	2.37
Large Stacks (range, about 100-183 m)	58	0.78	0.54	1.11	0.74	0.95
All sizes	615	0.90	0.27	1.33	0.84	3.00

The procedure presently recommended by the Department of Environment(1) (Dept. Health) has as its basis the Bosanquet, et.al. procedure. The Department's procedure includes two important modifications. First, an essentially neutral temperature stability condition is assumed to exist; and second, a factor of 75 per cent to the total calculated rise is applied. For a flare stack, a 50 per cent factor is used.

A comparison by Agrawal(22) of stable temperature gradient plume rise calculations made for an Alberta sulphur plant is shown by Table V-2 and indicates the variance possible using "accepted" methods.

TABLE V-2

Comparison of Plume Rise Calculations

Method		Momentum ft.	Thermal ft.	Total ft.
Bosanquet, et. al.	(23)	70	400	470
Alberta Dept. Health	(1)	50	420	470
Holland		50	180	230
Bosanquet	(24)	60	310	370
Briggs	(25)	--	300	300
Concawe		--	450	450

From a numerical model history match of measured ground level SO_2 concentrations, the best agreements were obtained using the Holland and Briggs methods; the Holland for wind speeds larger than 5 mph and the Briggs for wind speeds below this value. An interesting fact of this observation is that each method utilizes a different dependence on variables like volume throughput and wind velocity. The Holland formula indicates a direct proportionality of plume rise with volume throughput and an inverse proportionality with wind speed. In contrast the Briggs'expression shows a 1/3 power dependence on volume throughput and between a negative 1/3 and negative 1 power dependence on velocity (the variation depending on atmospheric stability). Thus sensitivity to volume throughput and wind velocity can be quite different when using either of the two different expressions of plume rise.

It is clear that considerable caution must be exercised in the use of a particular plume rise formula for stack design purposes. The subject still requires considerable research to develop a satisfactory plume rise model that will include all of the important factors particularly related to sulphur plant emissions. In the interim, industry generally accepts the Bosanquet et. al. modified calculation when used in conjunction with the Sutton or Pasquill formula because experience has shown that the resulting ground level concentration measured will be well within the ambient air standards. Certain situations may arise where dignificant topographical features may require more involved consideration of stack height calculations and industry and government should appreciate and utilize technical advances made in this regard.

V STACK DESIGN

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VI MONITORING PRACTISES

- A. Direct Monitoring
  - 1. Process Monitoring
    - a. Daily Plant Balance
    - b. Routine Operating Control
  - 2. Stack Emission Measurement
  - 3. Ambient Air Quality Monitoring
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MONITORING PRACTICES

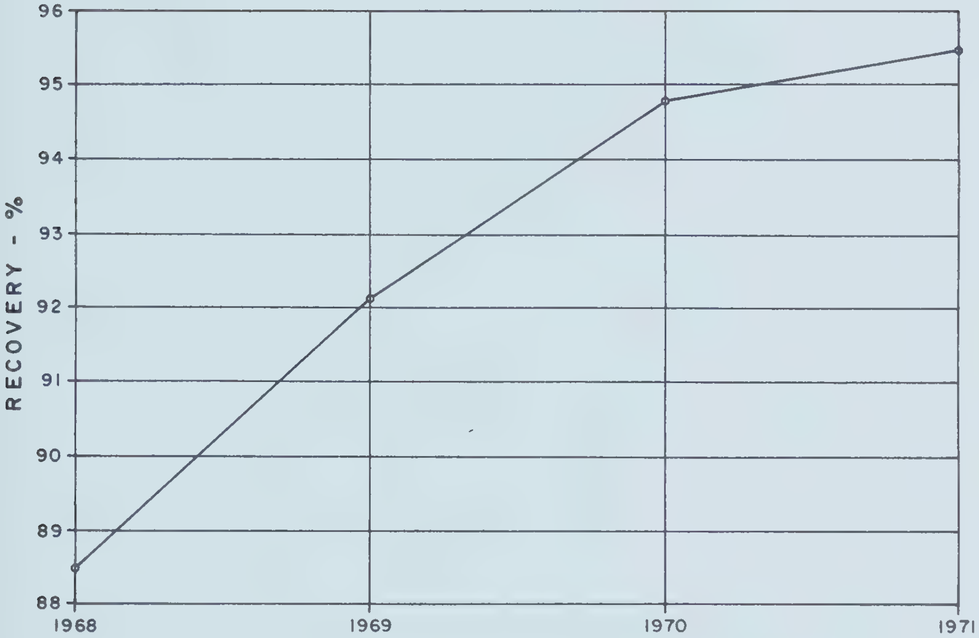
The sulphur recovery operations sector of the gas industry in Alberta since its inception in 1951 and particularly over the last five years, has devised a conscientious emissions surveillance program which, in its technical advancement, thoroughness and size, makes it unique in the world. The measurement and monitoring methods developed have assisted the industry in the understanding and upgrading of the sulphur recovery process with a corresponding reduction in emission levels. The increase of the overall recovery of sulphur in Alberta is demonstrated in Figure VI-1 which shows the sulphur recovery expressed as a percent of sulphur content contained in all gas produced (including flared gas) in Alberta.

A. DIRECT MONITORING

1. Process Monitoring

a. Daily Plant Balance

Due to diverse ownership of most gas processing plants and the requirements of the Oil and Gas Conservation Regulations, each gas processing plant maintains accurate production records. This involves a daily plant balance showing the gas and liquids received at the plant in comparison to the gas sold and products recovered or flared. With the knowledge of the composition of the gas and liquid streams from routine plant tests, the day's operations are evaluated with respect to recovery efficiency in order to effectively control the operation.



OVERALL INDUSTRY AVERAGE
SULPHUR RECOVERY IN ALBERTA - %

Figure VI - 1

b. Routine Operating Control

The most recently constructed gas processing plants have sophisticated analyzing and control systems. For those plants where such equipment is not installed, effective control of the processes is achieved by manual techniques. In the latter instance many plants perform wet tests, incorporating variations of the Tutweiller test to determine the hydrogen sulphide content, and a back titration to determine the sulphur dioxide content of gases from various stages of the process system to maintain operating efficiencies. In the larger and more recent plants, operating control samples are analysed using gas chromatography. Process control instrumentation is not a requirement by any regulatory agency. Nevertheless, as early as 1962, process monitoring was applied using gas chromatographs on a continuous basis in the interest of improving sulphur recovery efficiency operations. At the same time, to benefit from monitor data, it became apparent industry required increased knowledge of the Claus reaction and associated factors, such as the condition of the catalyst, changes in feed composition, operating temperatures and the hydrocarbon content of the feed which influence the conversion efficiency.

It is estimated that fifteen plants operating in Alberta now are using some form of process control in their sulphur recovery operations. All of these process control units are believed to be based on tail gas analysis using chromatography. Another approach using the principle of ultra-violet light absorption has been developed recently and is presently under consideration by a number of plants.

One concept in sulphur recovery operations of optimization of the process by closed loop control is indicated in

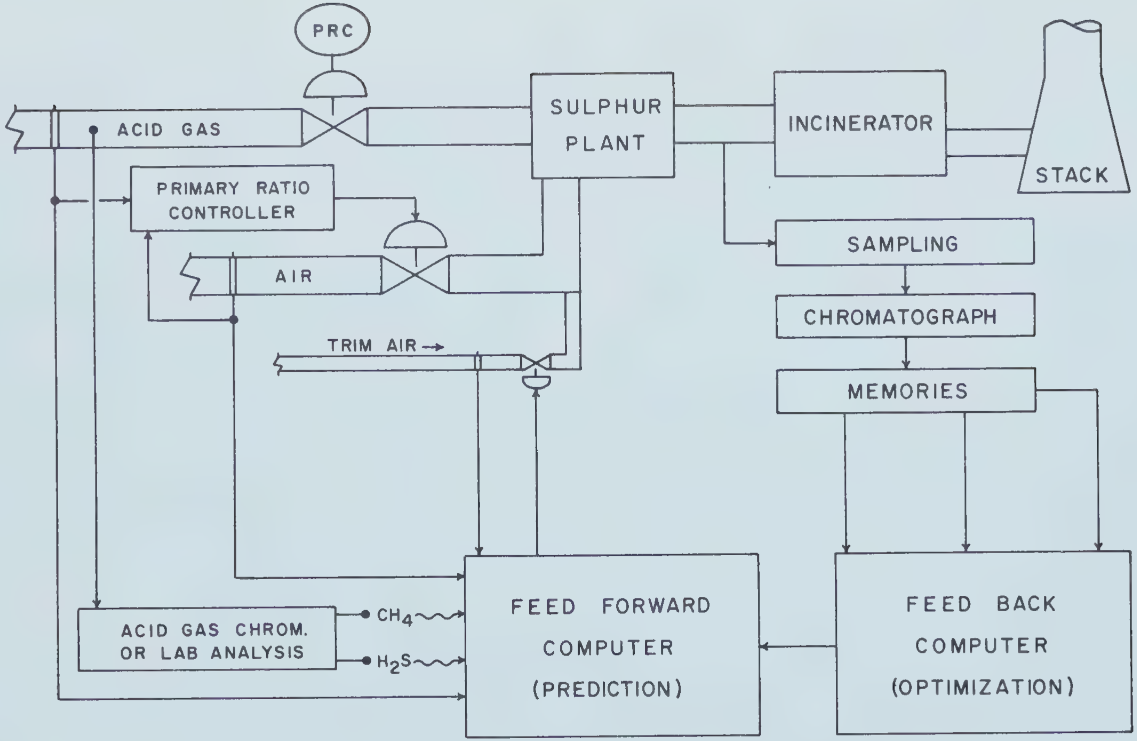
Figure VI-2. Information on composition and rate of acid gas feed are fed to an analog feed forward computer, while the H_2S/SO_2 tail gas ratio readings are supplied to a feed back computer. These data are weighted to optimize and control the process variables. One such installation has been made in an Alberta plant.

2. Stack Emission Measurement

Determination of the emission rate from a stack using conventional methods involves the measurement of the velocity and composition of the effluent gas. The test, which takes about eight hours to perform, is conducted in accordance with methods prescribed by the Department of the Environment. During the survey, every effort is made to hold the operating level of the plant steady at a minimum of 90 percent of the design or approved capacity of the plant.

The effluent velocity is obtained by running a series of traverses across the stack with a pitot tube to which a sensitive draft gauge is attached. Stack temperature is determined by a thermocouple in the gas stream while composition of the effluent is determined by chemical absorption of sulphur dioxide, carbon dioxide and oxygen from a sample of gas drawn from the effluent stream. After each test, a report is prepared showing the effluent velocity, composition, tons of SO_2 emitted and the plant efficiency calculations. This is compared to the plant material balance data and its calculated efficiency.

In 1970 the ERC Board required some form of continuous monitoring devices to be in operation for all plants recovering more than 100 long tons per day of sulphur. In response to this requirement, two types of systems have evolved. The first is one which gives a continuous record of the gas



FRENCH PROCESS OPTIMIZER FOR SULPHUR RECOVERY PLANTS USING GAS CHROMATOGRAPHY AND ANALOG COMPUTERS

Figure VI – 2

velocity and concentration of sulphur dioxide from which the sulphur emission rate is computed manually. The second provides a direct record of the quantity of SO_2 being emitted on a continuous basis. A block diagram of the latter type is shown by Figure VI-3.

Two methods are available for determining the composition of SO_2 in the stack. The first is by gas chromatography and the second utilizes ultra-violet light. The former has a sampling cycle of one analysis in anywhere from 8 to 12 minutes, depending upon the design of the chromatograph. The ultra-violet method provides an instantaneous, continuous analysis.

As indicated in Figure VI-3, the signals from the primary measuring elements are received by an analog computer from which a direct record of the long tons of sulphur or sulphur dioxide are displayed. The plant operators use this record to observe the emission from their operations.

Difficulties have been encountered in obtaining continuous operation of these devices. The major problems occur at plants with the older type corbel construction concrete stack or those which subsequently had been relined with stainless steel. The distance between the inner and outer sections of the latter stacks are in some instances as much as 10 feet. This makes it difficult to maintain high enough temperatures in the sample stream because of excessive heat losses from the sample lines. Also, in some stacks, refractory material, salts of various types or other materials from side streams admitted to the incinerator for efficient disposal, and other foreign material, lead to plugging of the sample probe and the velocity measuring device. These problems are gradually being over-

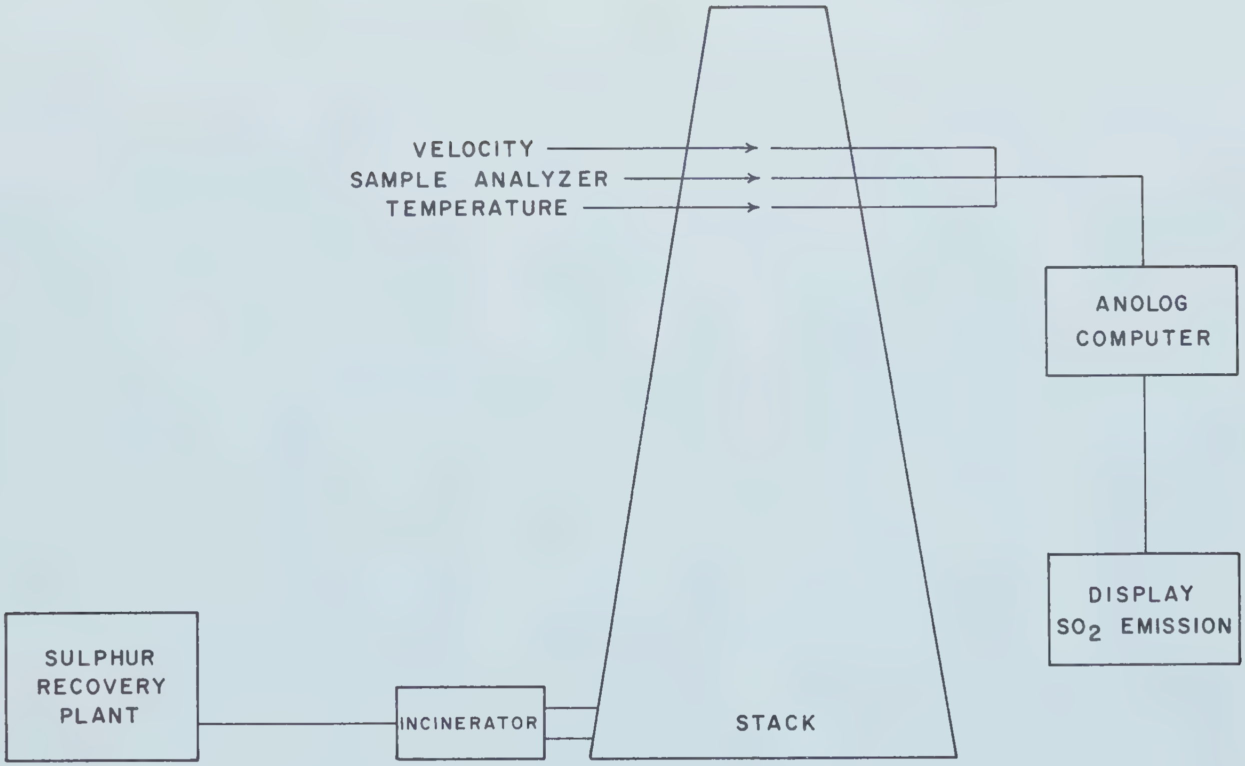


DIAGRAM OF CONTINUOUS MASS FLOW EMMISSION MONITOR

Figure VI - 3

come and on stream performance with reasonable accuracy is being obtained 90 percent of the time.

There are 40 sulphur recovery plants operating in the Province of Alberta, of which some 25 have a requirement for the installation of a continuous stack monitoring device. Of these, 15 have mass emission measurement based on ultra-violet analytical methods, and 7 use gas chromatography. Only three use concentration and velocity information to manually compute the emission rate.

3. Ambient Air Quality Monitoring

The ocean of atmosphere covering the earth is the repository of an enormous amount of waste material. Air has many self-cleansing processes which, if not overburdened permit the maintainance of a reasonable level of purity in the atmosphere. Waste material has natural (ash from forest fires, volcanoes, dust storms), as well as man-made (industrial effluents) origins.

The most important atmospheric process for handling wastes is simple dilution. There are 4.9×10^9 million cubic miles of "useful" air which could safely contain enormous quantities of foreign material if it was adequately dilute. When pollutants are discharged into the air, their dilation and diffusion are related to the prevailing meteorological conditions, which directly influence ambient air quality.

Ambient air quality monitoring by the sulphur recovery plant operators in Alberta goes back to 1958 when the first exposure cylinder stations were installed at a plant in southern Alberta. In 1960, the first continuous monitoring instruments were installed at sulphur plants. Parallel to the monitoring done by industry, the Department of Health (presently Department of the Environment) maintained surveillance of the air quality around gas plants.

A. EXPOSURE CYLINDERS

Exposure cylinder stations are widely used as a practical method of measuring total sulphation and hydrogen sulphide concentrations in ambient air. The exposure cylinder method gives a cumulative, rather than instantaneous, measure of air quality. It is a method intended to determine the relative sulphation from place to place and to indicate long-term trends in pollution level. The method is used to determine any pollution pattern over an area, and to detect trends in the values of sulphation and hydrogen sulphide.

A station is made up of two cylinders, one based on the lead peroxide method for total sulphation, and the other for hydrogen sulphide, using zinc acetate. The lead peroxide cylinder consists of a 100 cm^2 strip of sulphur free gauze fitted around a non-reactive cylindrical holder and coated uniformly with a lead peroxide (PbO_2) paste. When exposed to the atmosphere, the lead peroxide reacts with atmospheric sulphur compounds to form lead sulphate ($PbSO_4$). The sulphate is measured gravimetrically and reported as milligrams of SO_3 per 100 cm^2 per day.

For detection of hydrogen sulphide, a similar cylinder is wrapped with a 100 cm^2 strip of filter paper impregnated with zinc acetate ($Zn[C_2H_3O_2]_2$). Atmospheric hydrogen sulphide reacts with the zinc acetate to form zinc sulphide (ZnS). The sulphide is measured volumetrically and reported in the same units as total sulphation ($MgSo_3$ per 100 cm^2 per day).

For protection from mechanical injury and precipitation, both cylinders are sheltered in a small box with metal top and louvered sides.

The use of exposure cylinders goes back as far as 1932 to the Department of Scientific and Industrial Research in England. Since the original applications, subsequent research has been carried out to determine the effect of meteorological parameters on reaction rate and to eliminate sources of error in the preparation and analysis of the cylinders.(1)

Studies conducted on the accuracy of the lead peroxide method have indicated the following:

a. The formation of $PbSO_4$ is proportional to the concentration of SO_2 for the ranges encountered in the atmosphere;

b. The rate of reactivity is not significantly altered by wind speed or changes in relative humidity, but is affected by changes in ambient temperature or moistening of the lead peroxide surface. The reaction rate was also found to be a function of the PbO_2 particle size.

c. Total error of sampling and analysis is estimated to be in the order of 10 percent.

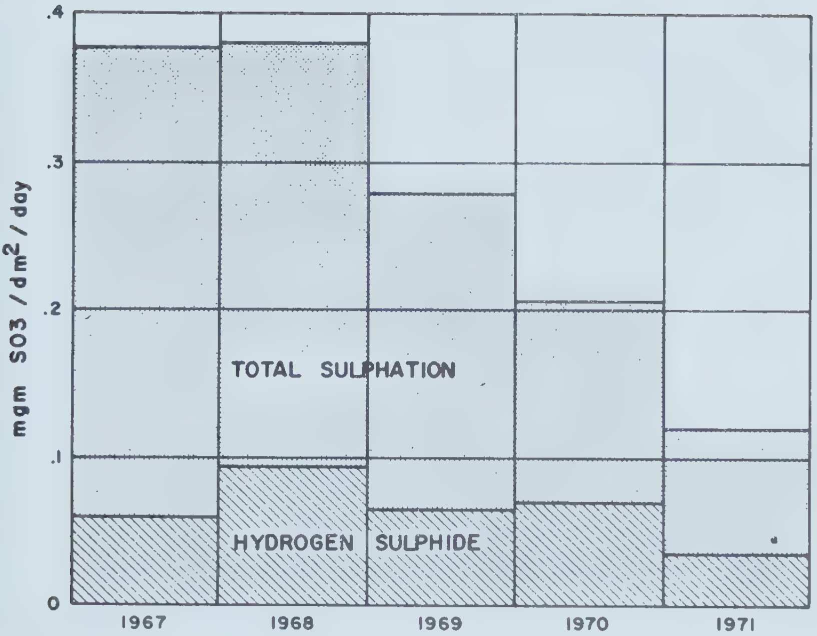
In standard use, care is taken in the preparation of PbO_2 paste to ensure a uniform and standard particle size. Moisture effects are virtually eliminated by proper use of the louvered shelter.

Further studies have indicated reasonable correlation between total sulphation and SO_2 concentrations (2, 3). One such study was carried out over an eighteen month period in the vicinity of one of Alberta's major sulphur plants (4). Good correlation was found to exist both between the exposure cylinders and wet chemical determination by the modified West Gaeke procedure. No variation in the rate of reaction of the lead dioxide was apparent from summer to winter. In fact, the exposure cylinder results closely followed the trend to higher sulphation values in the winter as indicated by the other two methods.

Great care is taken in the placement of the exposure cylinder stations. Locations of particular interest in the plant vicinity include hilltops, valleys, towns, farm houses, and recreational areas. Other stations are then located to cover the area on a predetermined grid system, with special attention paid to the prevailing downwind direction.

Exposure cylinders were in service in the vicinity of Alberta sulphur extraction plants at over 350 permanent sites in 1971. Plants utilize between 4 and 40 stations, depending on size. The cylinders are changed and analyzed at the end of each calendar month in accordance with standard practices set out by the Department of the Environment, and results are reported to the Department.

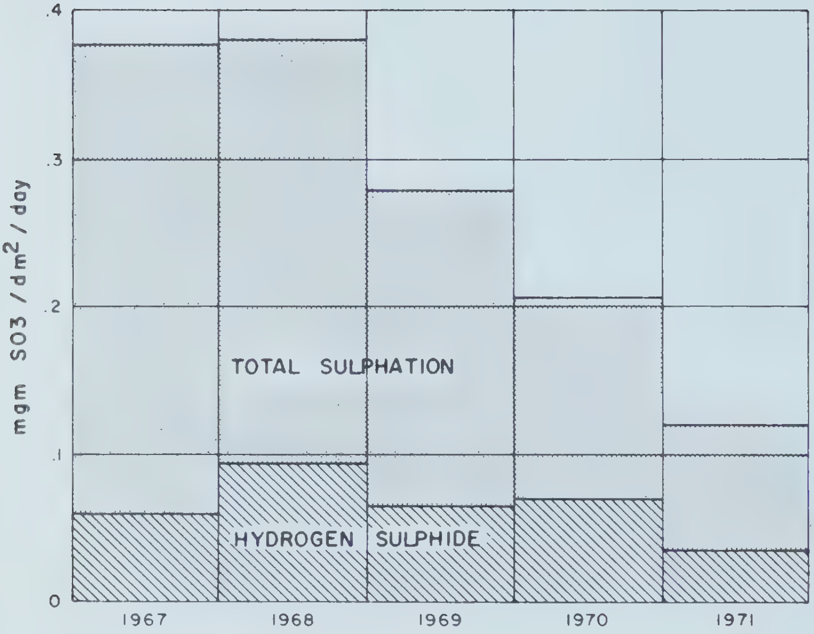
The network of exposure cylinders has faithfully recorded the air quality trends in the vicinity of Alberta sulphur plants for the past fifteen years. Distinct correlations have been noted between exposure cylinder data and sulphur recovery efficiency as plants have been improved. A good illustration of this is the record by one of the major sulphur plants in the Province, shown on Figure VI-4.



MAJOR SULPHUR RECOVERY PLANT IN ALBERTA

YEARLY AVERAGE TOTAL SULPHATION AND HYDROGEN SULPHIDE CONCENTRATIONS FROM EXPOSURE CYLINDERS

Figure VI - 4



MAJOR SULPHUR RECOVERY PLANT IN ALBERTA

YEARLY AVERAGE TOTAL SULPHATION AND HYDROGEN SULPHIDE CONCENTRATIONS FROM EXPOSURE CYLINDERS

Figure VI - 4

b. Dustfall Cylinders

The Department of the Environment has recently requested that sulphur plant operators maintain exposure cylinders for the measurement of sulphur dustfall. These consist simply of an open container, mounted 4 to 6 feet above the ground in the vicinity of the sulphur block. These are removed for analysis at the end of each calendar month in conjunction with the sulphation and hydrogen sulphide exposure cylinders. Results are reported as Tons Sulphur per sq. mi. per 30 days. There are approximately 300 such stations presently around sulphur recovery plants in Alberta.

c. Continuous Monitoring Devices

(i) Types

Sulphur dioxide in concentrations of physiological concern, may be measured in the atmosphere by one of four analytical techniques; conductivity, colorimetry, coulometry or flame photometry.(5) A number of commercial instruments embodying these principles are available. In the conductivity method(6), the electrical conductivity of a solution measured between two immersed electrodes is proportional to the SO_2 content of the air sample drawn through the solution. The colorimetric method uses a chemical test known as the West Gaeke procedure, which is based on the modified Schiff reaction. Coulometric analysis of SO_2 depends upon the redox potential established to titrate sulphur compounds as they are formed in solution. Flame photometry analysis of SO_2 utilizes the specific sulphur luminescence wavelength of 394 per mu provided by a hydrogen rich flame.

Much work has been done and is continuing to be done on the evaluation of sulphur dioxide field monitoring instrumentation for reliability and accuracy (7, 8, 9 and 10). Equipment designs have advanced to increase long term chemical and electronic stability of field instruments to maintain their sensitivity, and to reduce reaction interference problems. Solid state electronic circuitry, improvement in electrical switching mechanisms and greater pump reliability have all contributed to extending the unattended monitoring capabilities of some of the newer instruments.

Instruments used in the detection of hydrogen sulphide employ a colorimetric technique based on the reaction of lead acetate with ambient hydrogen sulphide. The instruments, generally referred to as "spot tape samplers", operate on a one-hour exposure of a section of lead acetate impregnated paper tape. Reaction with hydrogen sulphide to form lead sulphide causes a discoloration on the tape.

Due to the instability of the lead sulphide stain when exposed to air and sunlight, the tapes are interpreted, either manually within 24 hours after exposure, or automatically. Many of the instruments are now equipped with a built-in spot evaluator which measures the optical density of the discolouration at the end of each hour and transmits the value to be recorded on permanent charts.

In practice, these instruments are housed in a trailer and referred to as an Air Monitoring Station. In Alberta, the stations usually consist of an air conditioned trailer equipped with continuous monitors and recorders for sulphur dioxide, hydrogen sulphide, wind direction and velocity. Power to the trailer is supplied from standard networks or is generated on site.

(ii) Calibration

To ensure the highest degree of reliability and accuracy, a detailed calibration routine is followed for continuous monitors, employing the most accurate and technically advanced procedures available.

For some years, the established reference method for determining low level concentrations of sulphur dioxide has been the West Gaeke procedure. Recent developments in the permeation of gases such as SO_2, through a porous structure, has led to this method becoming a secondary standard to the West Gaeke method.

In the permeation system, the sulphur dioxide exuding from the tubes is mixed with a diluent gas stream, and the resulting mixture supplied to the instrument. The permeation rate of the sulphur dioxide is determined gravimetrically and the total gas stream flow rate is metered by a calibrated flow control device. During each calibration generally four concentrations within the range of the instrument are supplied to the instrument.

In order to assure that the permeation system is operating correctly, the sulphur dioxide concentrations delivered by the permeation tube systems are checked by the modified West Gaeke method. The procedure is carried out a minimum of once each month on all operating instruments in accordance with Department of the Environment Air Monitoring Directives.

Some instruments now in use contain an internal calibration mode, which is checked periodically, while the instrument is in operation. In the event of a deviation in the internal calibration, the instrument is immediately recalibrated by the permeation tube and West Gaeke procedures.

(iii) Site Selection

Since the purpose of the continuous monitor is to detect the maximum sulphur dioxide and hydrogen sulphide concentrations existing in the vicinity of a plant, care must be taken in positioning the instruments. Generally, a number of factors are involved in the selection of the optimum location for a trailer:

- Average wind direction: The instruments are generally located downwind of the plant in the direction of the most frequent wind.
- Topography: Where possible, the trailer is located on nearby hills or ridges where topographically induced turbulence effects should be noticeable.
- Pollutant Distribution: Accumulated data from the exposure cylinder networks are utilized to determine the location of the maximum sulphation level.
- Receptors: When two or more stations are being located, at least one is located in the general area of built up or cultivated areas, where potential pollutant effects may be most damaging.

Once the general location has been chosen, the specific site is determined on the basis of accessibility, absence of structures which may interfere with the micrometeorology of the site, and absence of any obvious sources of contamination.

The number of trailers and length of monitoring time depends on the size and location of the plant. The Department of the Environment requires that monitoring be conducted for at least two months of the year at thirty-five sulphur extraction plants in Alberta. Of these, fourteen plants maintain between one and seven stations continuously. In 1971, continuous air quality monitoring at sulphur plants in the Province amounted to approximately 377 trailer-months, representing a cost to industry of about half a million dollars.

(iv) Data Transmission

The current trend in Alberta is to transmit or telemeter air quality data from several remote locations to one central control room or operation centre. This procedure permits the continuous image of the air quality to be monitored as indicated by the isolated instruments.

Analog telemetry is accomplished by using one of several techniques: A DC voltage, frequency shift variable keying, frequency pulse with keying, or by digital or binary pulse techniques. Short-haul radio links, rather than telephone lines or dedicated cable, permit easy location changing of monitoring trailers. Line-of-sight between relevant antenae is not necessarily a requirement, but low power and high-gain antenae are mandatory.

4. Plume Monitoring

Because areas of SO_2 stressing may occur at locations well removed from the point of emission as well as near a plant site the airborne measurement of plume structure and position may be important considerations in any emission analysis. In order to complete the picture of atmospheric transport, a method of measurement is required that will allow the plume concentration profiles to be mapped under various synoptic conditions.

During the last decade a method for remote measurement of some atmospheric gas burdens (called correlation spectroscopy)(11) has been pioneered and developed. This technique compares a replica of an adsorption spectra to a dispersed light beam which has passed through the target gas. The quantity of the gas in the light beam is determined by measuring the intensity of the energy in selected wavelengths. The light source for field measurements can be either natural sunlight or an artificial lamp located at a distance from the instrument. Presently available is a portable system that can be mounted in a vehicle for rapid traverses of the plume in any desired location. Such versatility makes it possible to measure total gas burdens or gas concentrations at specific locations.

In order to measure total gas burden the instrument is tuned to respond to the ultra violet component of natural sunlight. The viewing field of the sensor is directed vertically upward through the plume as illustrated in Figure VI-5. In this configuration, the total amount of SO_2 gas in the plume above any particular point is measured. The amount of SO_2 burden above the point can be expressed as a weight per unit area (milligrams per square meter) or as parts per million times the optical path length through the plume (ppm meters).

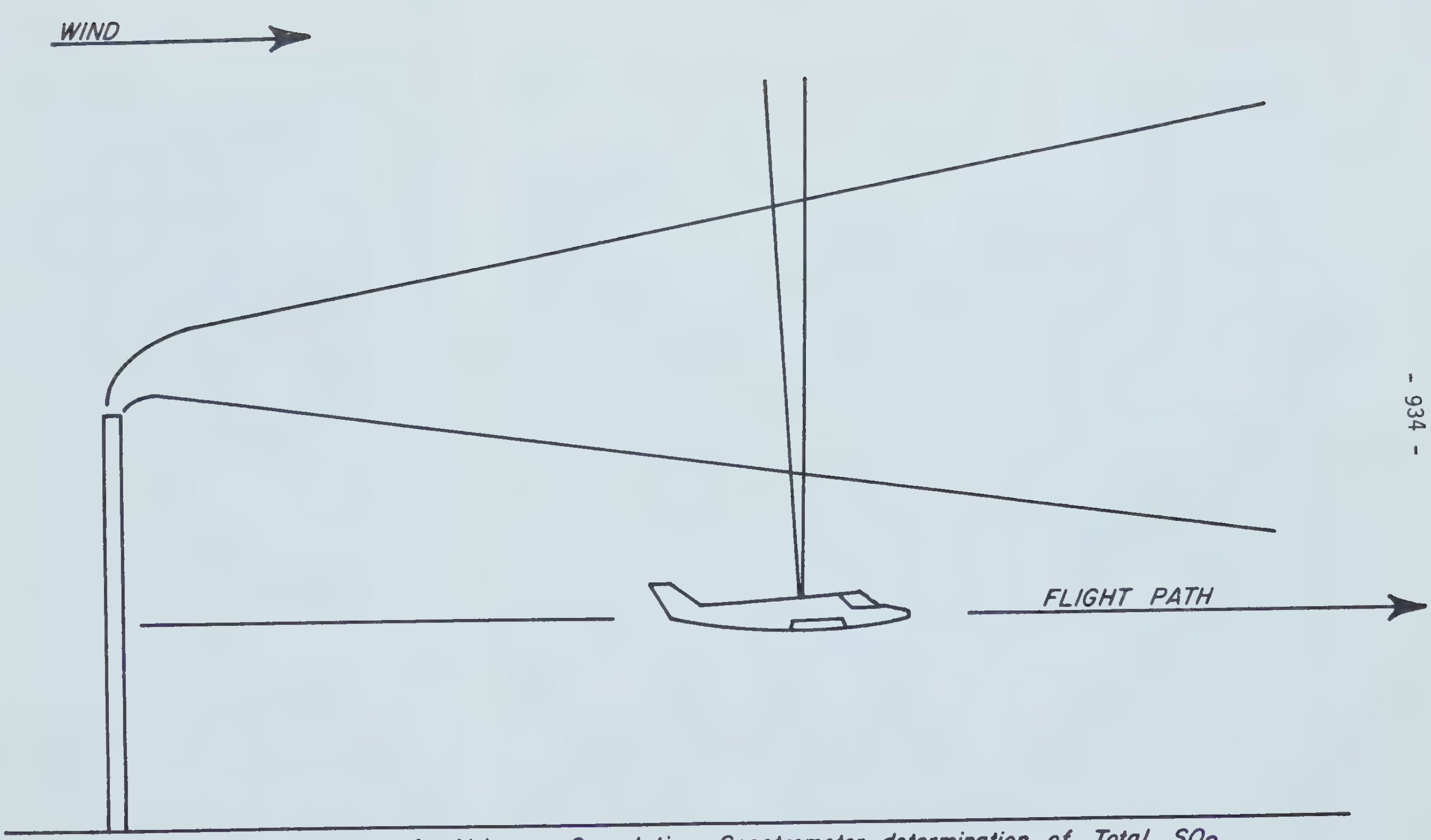
In order to measure concentration profiles in the plume, the light path over which the instrument senses the gas burden must be reduced and contained. This is accomplished by using an artificial light source (quartz-iodine) and reflecting the light beam around the perimeter of an aircraft with special mirrors attached to the aircraft wing tips and tail cone. The ultraviolet beam then enters the aircraft cabin and the spectrometer from the opposite side of the aircraft to the light source. Since the light beam is restricted to a closed path around the aircraft, the instrument senses the concentration at the aircraft location.

By selecting flight lines of appropriate horizontal and vertical spacing, horizontal and vertical profile sections of the plume can be plotted. The technique is depicted in Figure VI-6 while results of such a survey are depicted in Figure VI-7.

5. Data Interpretation and Reporting

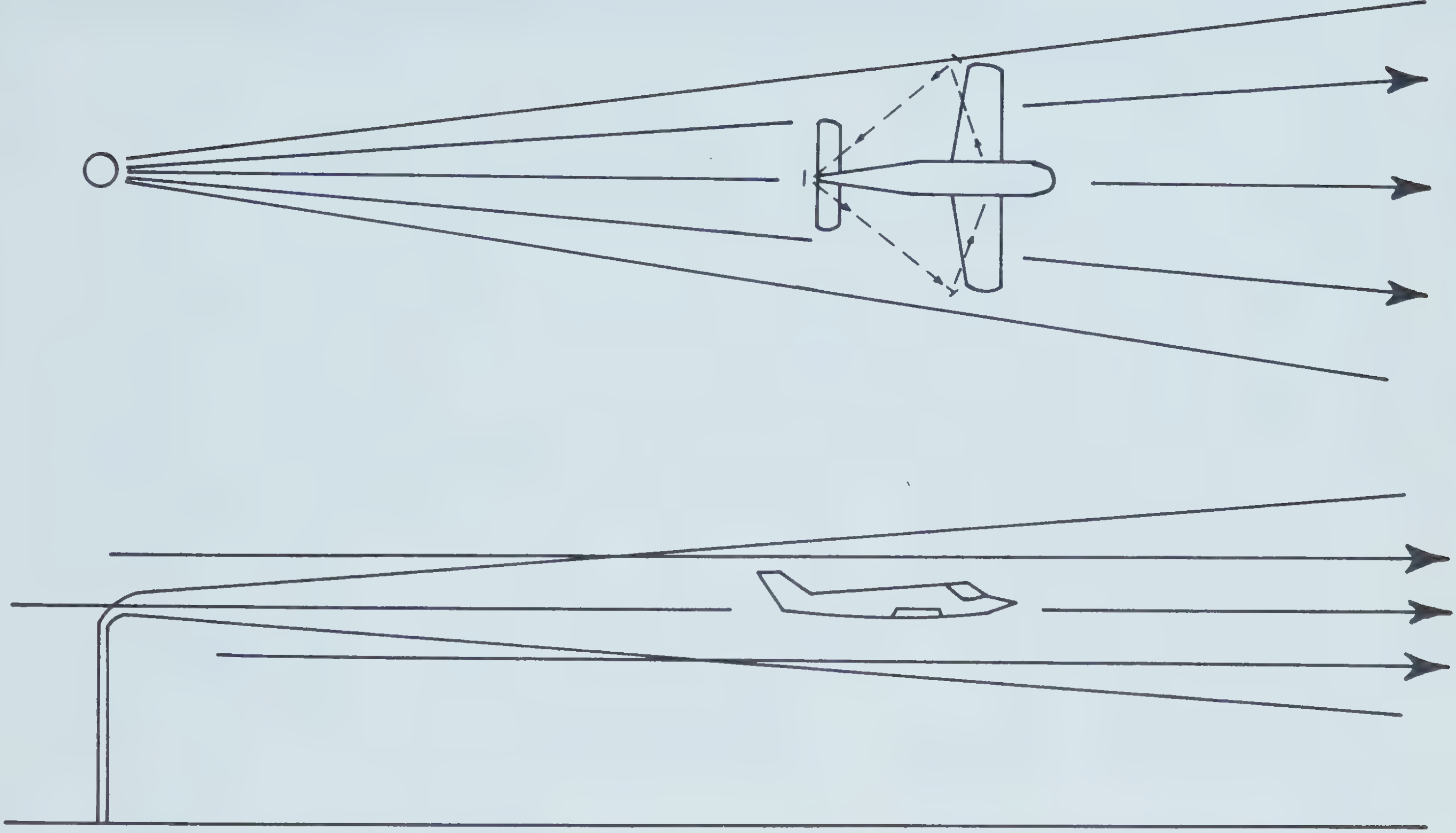
Over the past several years, procedures have been developed for data interpretation and presentation which assure the optimum utilization of collected air monitoring data from surface stations.

The Department of the Environment has recently standardized reporting practices through the issuance of a series of Air Monitoring Directives. In compliance with these, the plant operator each month submits a comprehensive report to both the Department of the Environment and the the Energy Resources Conservation Board. This report includes details of the monitoring network, results from all monitoring instruments, exposure cylinders, and sulphur dustfall stations, and plant operating data for the month. Reference is also made to any report of SO_2 or H_2S concentrations exceeding the Ambient Air Quality Standard, and a description of remedial action taken.



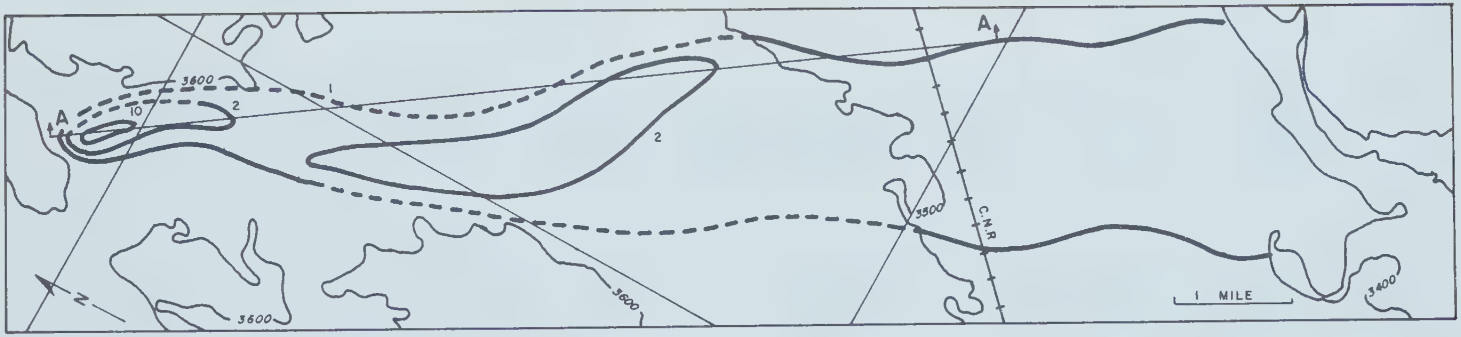
Idealized Illustration of Airborne Correlation Spectrometer determination of Total SO_2 burden in plume using ambient light.

Figure VI-

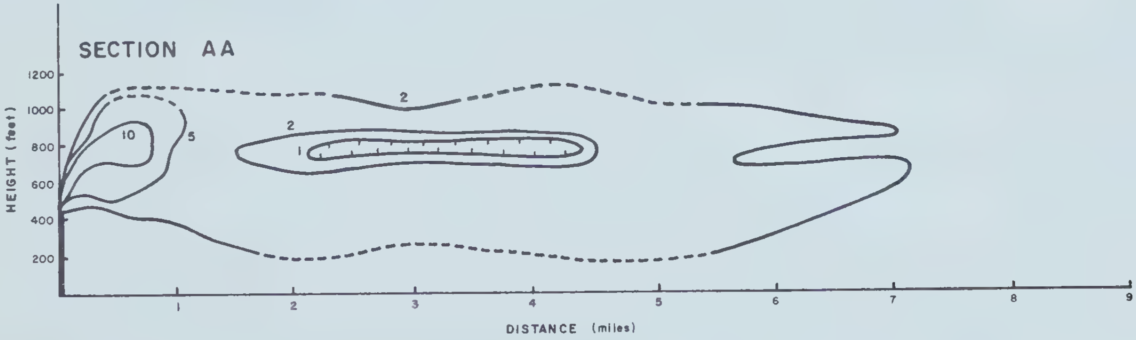


Idealized Illustration of Airborne Correlation Spectrometer determination of SO_2 plume profile using closed circuit light system.

Figure VI-6



BALZAC PLANT EXHAUST SO_2 PLUME (at 600') SO_2 Contours in ppm



BALZAC PLANT - SOUTH SO_2 PLUME IN PLAN VIEW & PROFILE

Figure VI - 7

B. INDIRECT MONITORING

1. Atmospheric Corrosion

During the last 25 years, some interest has been shown concerning mechanisms of atmospheric corrosion. A number of survey on the corrosion rates of metals have been conducted in the last few years in Europe, the United States and Canada. These have been principally in industrial urban environments where several atmospheric pollutants may interact with possible synergistic effects. A program was instituted in 1957 to monitor atmospheric corrosion rates throughout Alberta.

The corrosion coupons and samples utilized in Alberta were chosen to represent materials that may be subject to corrosive damage in the vicinity of sulphur recovery plants. Such materials as used galvanized telephone wire, two types of common barbed wire, and two mild steel coupons, one of which is zinc coated, are used. In addition, the stations used in Alberta include four samples of common house, barn and implement paints.

The corrosion station is analagous to the exposure cylinder in that it gives cumulative, rather than instantaneous indications of pollution effects. Moisture effects, temperature variations, and climatic conditions can have a marked effect on corrosion rate. For this reason, stations are exposed for at least one year and great care must be taken in interpretation of the results.

In 1971, reference stations were established at eight different locations throughout the province. These were chosen to establish background levels of atmospheric corrosion that may be associated with such factors as urban pollution, meteorological conditions and agricultural operations. Stations were also established in remote plains areas, where corrosive action is expected to be minimal. As a check on repeatability of the measurements, two stations are maintained at each location. The reference stations are changed and analyzed once a year.

A number of Alberta sulphur plants have now adopted the corrosion station as a monitoring tool exclusive of regulatory requirements. At the present time, at least nine sulphur plants in Alberta maintain sets of Corrosion Stations in their surrounding areas. In 1971, this private network totalled almost 100 individual stations.

The location of the corrosion stations in the field is chosen with the same care and in the same manner as for any monitoring device to provide information that is most meaningful and most easily interpreted. They are set out generally on a pre-determined grid system with locations selected on hilltops, in open areas, near farm houses and in recreational areas. Where an exposure cylinder network is also maintained, the corrosion stations are usually placed in conjunction with the exposure cylinders. This allows correlation of observed atmospheric corrosion with total sulphation.

Based on the reference results to date, the most corrosive atmosphere appears to be associated with agricultural activities. Urban centres indicate slightly lower corrosion rates, similar to remote humid regions. Plains and low brush regions as expected, indicate low corrosion effects. Corrosion rates around isolated sulphur plants were found lower than those in urban situations or in rural areas where air-borne fertilizer dust or acid vapours may occur from agricultural operations.

The use of corrosion stations in Alberta represents a unique development in monitoring of pollution effects in that it is only in Alberta that stations are maintained to monitor the atmospheric corrosive effects resulting from a single isolated industry.

2. Remote Sensing

a. General

Remote sensing is the technology of obtaining information about a target without having the sensor come in contact with it. The human eye is the oldest and one of the most sophisticated remote sensors. A camera similarly obtains data and records it on film; other sensors and sensor systems "look at" targets for study and obtain particular data about them.

All remote sensing instruments accomplish their function by virtue of their being sensitive to electromagnetic energy that is reflected or emitted from the target. The process of reflection is "active" and is the result of the target being illuminated. Part of the illumination energy is directly reflected at or near the target surface. The quantity and quality of the refelction gives target shape, colour, and tone information to the remote sensor. The eye and the camera permit the distinguishing of objects based entirely on the reflections which produce impressions and images of target characteristics. The process of emission from a target occurs whether it is illuminated or not. Emission is a "passive" process and is an inate property of all matter in some frequencies. For example, radio activity is a passive property of some objects and occurs regardless of the illumination present. All objects that have a temperature above absolute zero emit IR energy randomly into space. The intensity of the emission is proportional to a power of the absolute temperature. To take advantage of this relationship, instruments have been developed that are sensitive to emitted energy which permits the identification and characterization of targets.

It is important to recognize that the sole purpose of remote sensing (a technology involving many techniques) is to make it possible to identify and characterize targets in the environment based on their spectral properties. Since all objects have characteristic spectral signatures, it follows that many targets that are "invisible" or have obscure signatures in one part of the spectrum, may produce pronounced spectral effects in other parts. Hence the need in general environmental research, to employ many remote sensing techniques. For example, if SO_2 stress in coniferous trees is not identifiable in the visible using colour films, it may be identified according to its thermal signature in another spectrum range.

b. Photographic Techniques

Wave lengths in the visible spectrum may be registered with black and white, and colour film. More recently, rather exotic film formulations with unusual colour registrations have become available. One useful film is called "false colour" IR, which has pronounced sensitivity in the yellow, orange, red, and very short images on this film are very unlike true colours, hence the term "false colour".

FCIR film has a strong response to vegetation. Plant cells containing chlorophyl reflect in the red but this colour is normally masked by the presence of an abundance of green energy. The red is therefore seen only if blue-green filters are employed or if the film formulations are insensitive to blue and green.

The reflectance of red energy by vegetation is a tool that can be employed in the diagnosis of certain vegetal stresses at some plant growth stages. In general, the quality and quantity of red reflected from vegetation is governed by leaf morphology, and physiological condition. Healthy, green, turgid vegetation reflects strongly in the red and photographic IR regions.

The useful interpretation of FCIR photos to obtain vegetation stress is very much a "black-art" and the talent is acquired mainly by long experience. Films and formulations change annually, and exposures and developing chemistry are sensitive and difficult to control. Nevertheless, it is a useful technique in environmentology.

3. Vegetation Stress

During many days of the vegetative season, there are periods when vegetation is likely to be under normal environmental stress. Such stresses are caused by the surplus or shortage of soil water, surplus or shortage of heat, surplus or shortage of nutrients, etc. In natural stands, the variation is enormous, particularly in more severe terrain. In such cases, earth-sun geometry causes some hill sides and slopes to become over heated and to have thin or gravelly top soil supporting a limited plant population. Moreover, these natural stresses vary through the day and season. It is therefore very important that aerial photography and FCIR film be used with these considerations in view.

4. Soil Sampling

All effluents discharged into the atmospheric environment are eventually absorbed by various life cycles in nature which soon become involved at the surface of the earth. Indications of the deposition of such materials on the surface may be found in the vegetation and soil. This is particularly true of elemental sulphur dust which, though capable of becoming airborne, settles to the soil surface very near the gas plant. Nyborg and Schurer(12) show that "When elemental sulphur is added to soil, certain soil bacteria (of the genus Thiobacillus) oxidize the sulphur to sulphuric acid as follows:

$$2S \pm 3O_2 \pm 2H_2O \longrightarrow 2H_2SO_4$$

The rate at which sulphur is oxidized varies greatly from soil to soil and depends on such conditions as temperatures, moisture, aeration, fineness of the sulphur deposited, and number of Thiobacillus bacteria present in the soil. The acidification reaction proceeds most rapidly when soils are warm, moist, and well-aerated. Rate of oxidation may be initially limited by number of bacteria, but after sulphur is deposited the bacteria soon build up to their maximum number. Finely-powdered sulphur is oxidized much more rapidly than course sulphur. Sulphur finer than 100 mesh may be oxidized about 50 times more quickly than sulphur 5 to 10 mesh in size. Lumps of sulphur (say greater than 1 inch in diameter) are oxidized very slowly until broken down in size.

Most natural soils have pH values in the range of 6.0 to 8.0 which is suitable for good growth of the majority of plant species. Some very sensitive plants, such as alfalfa, do not grow well when pH is below 6.0, but most species grow fairly well at pH values down to 5.0 to 5.5. In the pH range of 5.0 to 5.5, the aluminum in soils, which is toxic to plants, starts to become soluble. Some plant species are much more tolerant than others to aluminum toxicity (and to other toxicities found in acid soils) and will grow after a fashion in soil as acid as pH4. However, soils of less than pH4 are essentially barren.

Oxidation of 1 or 2 tons of sulphur dust per acre will lower soil pH by about 2 pH units, and oxidation of more than 3 or 4 tons* will acidify most soils to less than pH4 and will retard or prevent plant growth. The first effect of acidification is a change of species of plants growing on a soil to those most tolerant to acidity. If acidification continues, plant growth will gradually disappear altogether.

Soils are sampled generally from surface to 6" of depth and sometimes in addition, below this depth to qualify the extent of sulphur acidification of the soil. The samples are prepared for testing by drying, grinding and screening. pH and conductivity measurements are made on the water phase resulting from a soil-water mixture shaken for 30 minutes followed by a settling period.

Western soils are usually high in free lime and this reflects the geological origin of the soil and has little effect on crop growth. Normal sulphur or sulphur dioxide conversion to sulphuric acid in the soil or in the atmosphere results in conversion of this lime to $CaSO_4$, an insoluble salt with little adverse effect on crop growth. Chemical reactions with sodium salts in the soil result in a soluble sulphate being available to plants as a fertilizer.

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* It is assumed the author means 3 or 4 tons "per acre".

In nature the soil system has a great capacity to absorb and decompose waste materials. Soil is enormously complex and if its various processes are not overtaxed, it can accomodate many minor "foreign" intrusions.

C. SUMMARY

The Canadian Petroleum Association believes that the application of emission standards is an inappropriate approach to environmental management, and further submits that "emissions" as such, are not intrinsically related to anything except gas-plant processes. The engineering approach of the last 15 years has lead pollution management and abatement into a situation that satisfies design criteria, but almost totally neglects the most important consideration, vis: it is the receiving environment that is paramount; the environment will determine where the gas-plant and stack should be; the environment will determine what the acceptable emissions level should be, and therefore, what process modifications should be made.

The environment is very resilient, it has the capacity to absorb, even suffer, and then recover if it has not been too seriously imposed on. This natural built-in capability of nature to absorb, makes it necessary to watch natural processes carefully, in order to differentiate between natural and induced environmental changes. This alludes to the pointless program of purely emissions control, to the exclusion of environmental monitoring. Some facets of nature are able to absorb more effluent than others. Regional considerations suggest that gas-plant emission be governed by meteorological and environmental conditions.

It seems to us then, that before increased gas-plant efficiencies are legislated, consideration must be given to the receiving environment. If it can be established that gas plants, on an individual basis, have caused no environmental degradation, there is no logic to requiring increased sulphur recovery efficiencies.

D. REFERENCES FOR SECTION VI- MONITORING PRACTICES

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VII SULPHUR RECOVERY, RESEARCH AND DEVELOPMENT

A. The Sulphur Plant
  1. General
  2. Front-End Reaction Furnace
  3. Claus Catalytic Converters
    a. General
    b. New Catalysts
    c. Ratio Control
    d. The Temperature Factor

B. Tail Gas Incineration

C. Tail Gas Sulphur Recovery
  1. Methods
  2. Economic Considerations

D. References

VII SULPHUR RECOVERY, RESEARCH AND DEVELOPMENT

A. THE SULPHUR PLANT

1. General

While it is commonplace to refer to the overall efficiency of sulphur recovery in a sour gas processing plant it is important to recognize that this overall figure is the combination of the efficiencies of a number of component parts in the total hydrogen sulphide to sulphur conversion system. Within the sulphur plant itself there are three clearly differentiated sections - the front-end reaction furnace, the Claus catalytic converter and the tail gas treating section. Each of these sections will be considered separately and the industry's efforts to improve the performance of each one will form the basis for subsequent paragraphs. Figure 1, however, is of importance at this stage as it illustrates the interdependence of these various stages and the manner in which the efficiency of operation of an upstream unit determines the load on a downstream component. This is of particular importance when considering tail gas desulphurization methods and costs.

Figure VII-1 also illustrates one of the biggest problems in achieving high conversion efficiencies - the concentration problem. As we progress through the system the residual unrecovered sulphur values become progressively diluted by other reaction products and added inerts, and are thus harder to remove. By far the largest proportion of the hydrogen sulphide removed from the sour gas is converted to

THE CONCENTRATION PROBLEM

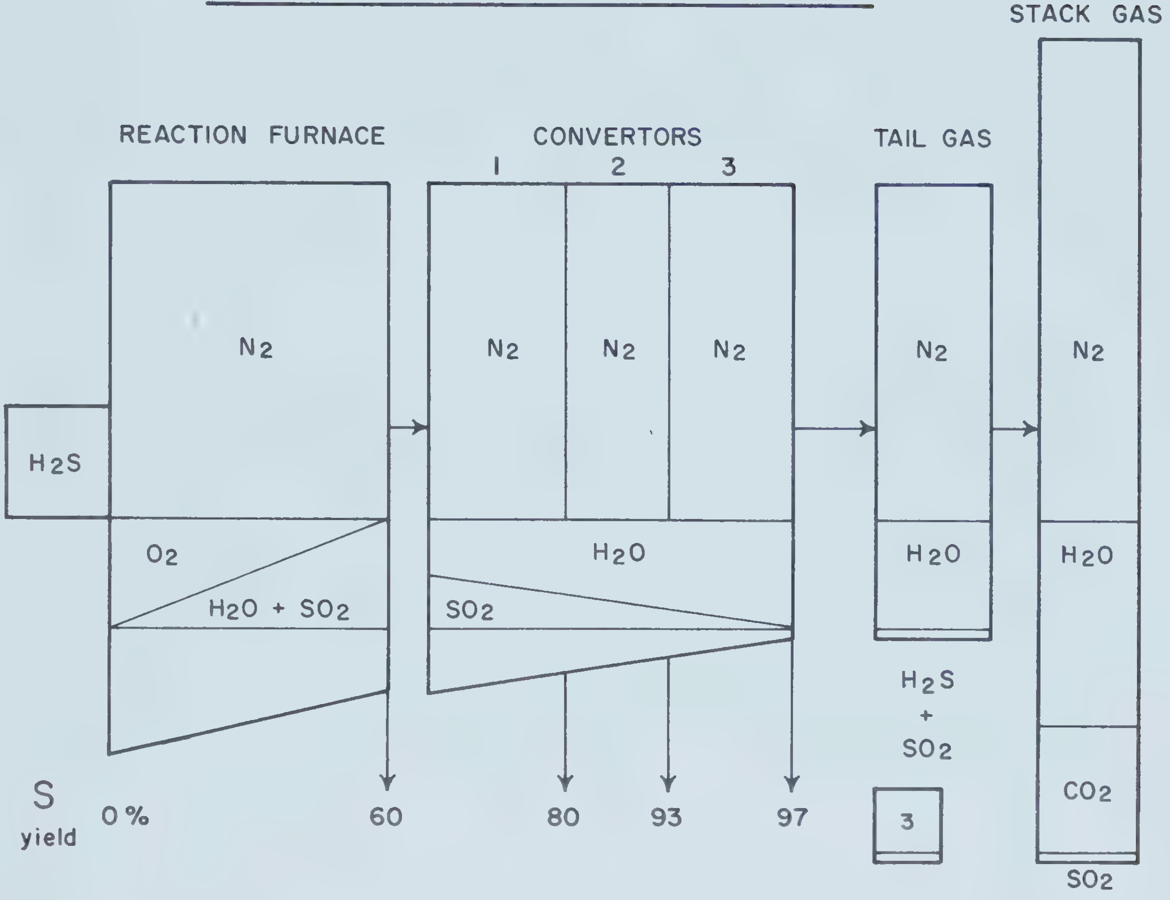


Figure VII - 1

sulphur in the front-end reaction furnace. Figure VII-1 indicates an average 60% conversion although this depends on many factors to be discussed later. Here, in the reaction furnace, air is added to sustain combustion and the first major dilution of the sulphur content occurs; the nitrogen of the air is inert and is simply "a passenger" from this point on. Enriched oxygen feeds have been investigated and the TRW S-100 process, using liquid oxygen with no nitrogen diluent, is presently being developed. It is, however, not adaptable to current sulphur plant operations and is sensative to liquid oxygen pricing in such a manner as to make it impractical for large scale Alberta sulphur plant operations at this time. Such very high temperature processes using what in essence is "space age" technology may, however, represent a next generation replacement for the front-end reaction furnace.

The conversion load placed on the Claus catalytic stages clearly depends on the efficiency of the front-end reaction furnace. Since each of these catalytic stages converts the feed received from the previous stage to an equilibrium point the sulphur yield at each stage is determined in part by the efficiency of the previous stage. Industry has done much to improve the overall efficiency of the Claus converter section of the system, both by increasing the efficiency of operation of the individual stages and by increasing the number of stages. Single stage Claus trains are virtually unknown in larger Alberta plants, while three stage converters are now common and even four units in series are available.

The sulphur content of the tail gas stream is obviously determined by the efficiency of operation of the upstream units. The figures of sulphur yield used for purposes of illustration in Figure VII-1 indicate a 3% sulphur content in the tail gas. Under the new ERCB guidelines incineration of this level of sulphur containing tail gas and venting to the atmosphere would not be acceptable for plants with over 1000 tons per day sulphur throughput. Since 97% overall conversion in a three stage Claus plant is a high conversion efficiency and close to optimum with present plant design, the possibility of tail gas desulphurization before incineration and atmospheric venting has now become an important consideration. This third phase of sulphur plant operation will receive detailed attention in a subsequent paragraph.

Stack gas dispersal, meteorological and topographic factors that influence the ability of the environment air volume to accept and dilute effluent, natural conversion of gaseous pollutants to non-toxic end products and many other factors external to the plant are all aspects of the problem of handling the residue from an otherwise highly efficient industrial chemical conversion system. The gas processing industry has not been satisfied with the"dilution solution to pollution". It has worked continually to improve the efficiency of each component of the sour gas processing system thus minimizing environmental contamination not simply by effective dispersal techniques, but by reducing the total waste effluent from its plant operations. How these improvements in plant operating efficiency have been accomplished and how the industry continues to tackle the ever harder problem of moving closer to the elusive goal of 100%-perfection-is the subject matter of the following sections.

2. Front-End Reaction Furnace

The overall efficiency of a sour gas processing plant is determined by the performance of its several component parts. Current emphasis on environmental quality control has focused interest on improvements in downstream units of the plant process stream. Particular attention has been paid to the Claus catalytic section and to tail gas clean-up processes. These downstream components, however, do no more than handle that part of the sour gas feed stream that is not converted to product sulphur in the front-end reaction furnace. What is sometimes forgotten is that under normal circumstances more than 50% of the conversion of hydrogen sulphide to elemental sulphur takes place in the front-end reaction furnace. What is being done to optimize the conversion efficiency in this first section of the typical sulphur plant?

Over the past several years, attention has been directed to achieving better percentage conversions in the front-end reaction furnace. This has led to a wider recognition of the complexity of the chemical processes occuring in the reaction furnace and, in turn, to a re-examination of some design factors not previously considered to be of crucial importance. By and large, design criteria have been based on the assumption that the overall stoichiometry shown in equation (1) serves to describe the process adequately, and refinement, where necessary, need not go further than dividing this process into two steps shown in equations (2) and (3) with additional consideration being given to the equilibria between various forms of the product sulphur indicated in equation (4).

$$6\ H_2S + 3\ O_2 \rightleftharpoons 6\ H_2O + \frac{6S_x}{x} \qquad (1)$$

$$2\ H_2S + 3\ O_2 \rightleftharpoons 2\ H_2O + 2\ SO_2 \qquad (2)$$

$$4\ H_2S + 2\ SO_2 \rightleftharpoons 4\ H_2O + \frac{6S_x}{x} \qquad (3)$$

$$8\ S \rightleftharpoons 4\ S_2 \rightleftharpoons 2\ S_4 \rightleftharpoons S_8 \quad \text{etc.} \qquad (4)$$

Even a cursory examination of equations (1) to (4) makes it clear that they do not tell the whole story. It is well known, for example, that sour gas process streams typically contain measureable concentrations of molecular hydrogen downstream of the front-end reaction furnace. Indeed, this hydrogen can be used to advantage in some tail gas clean-up processes. None of the equations shown above give any indication where this hydrogen is produced in the furnace processes. Sulphation of the catalyst beds has long been a problem in some gas processing plants and is known to be due to the production of sulphur trioxide upstream of the catalyst section. Again equations (1) through (4) give no indication of where this sulphur trioxide might originate.

Largely as a result of the detailed hydrogen sulphide flame studies of Merryman (1) and the extensive work on the combustion of gaseous sulphur compounds recently reviewed in excellent detail by Cullis and Muleaky(2), It is now well established that the true picture of the hydrogen sulphide combustion chemistry taking place within a front-end reaction furnace is probably more completely illustrated by the sequence of chemical reactions presented in Table VII-1. The complexity of these processes in no way invalidates the general statements contained in equations (1) through (4). Many of the species shown in Table VII-1

SOME FURNACE REACTIONS

$H_2S + O_2 \longrightarrow HO_2 + HS\cdot$

$H_2S \longrightarrow HS\cdot + \cdot H$

$H\cdot + H_2S \longrightarrow HS\cdot + H_2$

$HS\cdot + O_2 \longrightarrow SO + \cdot OH$

$\cdot OH + H_2S \longrightarrow H_2O + HS\cdot$

$\cdot OH + HO_2 \longrightarrow H_2O + O_2$

$SO + O_2 \longrightarrow SO_2 + O\cdot$

$O\cdot + H_2S \longrightarrow \cdot OH + \cdot SH$

$SO + O\cdot \longrightarrow SO_2^* \longrightarrow SO_2 + h\nu$

$SO + SO \longrightarrow S_2O_2$

$HS\cdot + HS\cdot \longrightarrow H_2 + S_2$

$HS\cdot + HO\cdot \longrightarrow H_2O + S$

$S + O \longrightarrow SO$

$S\cdot + S\cdot \longrightarrow S_2$

$SO_2 + O + M \longrightarrow SO_3 + M$

$SO + O_2 + M \longrightarrow SO_3 + M$

$SO_3 + H_2 \longrightarrow SO_2 + H_2O$

Table VII - I

are short lived intermediates which probably never emerge from the front-end reaction furnace, but are nonetheless essential parts of the overall front-end reaction furnace chemistry. The reactions in Tavle VII-1 also give a clear indication of where hydrogen and sulphur trioxide can be produced in the overall system.

While much is known about the chemistry of the reactions shown in Table VII-1, the bulk of the work has been done under conditions that bear little relationship to the high temperature and high flow rates characteristic of a front-end reaction furnace. The kinetics of most of the processes depicted in Table VII-1 have been studied at temperatures well below the 1700-2200 degree Farenheit characteristic of the front-end furnace. Relatively little is known about the effect of such materials as CS_2, COS, CO_2, amines, ammonia and hydrocarbons on these reactions. All of these species are commonly found in the sour gas feed stream of sulphur plants. Carbon disulphide and carbonyl sulphide are also formed in the front-end reaction furnace primarily from the small hydrocarbon carry over from the amine stripper immediately upstream of the furnace. CS_2 and COS are both important and troublesome components in the sulphur plant tail gas. Many tail gas clean-up processes currently being recommended for use do not remove CS_2 and COS and thus the lower limit of clean-up using these processes cannot be below the concentration level of CS_2 and COS in the tail gas. The control of COS and CS_2 formation in the reaction furnace is therefore of very considerable importance as illustrated in Figure VII-2.

During the past two years the industry in Alberta has mounted a special research effort to examine a whole

COS : CS_2

FORMATION

DECOMPOSITION

$$CO_2 + H_2S \rightleftharpoons H_2O + COS$$

$$COS + H_2S \rightleftharpoons H_2O + CS_2$$

$$CH_4 + S \longrightarrow H_2S + CS_2$$

$$CH_4 + H_2S + (H_2O) \longleftarrow H_2 + CS_2\ (COS)$$

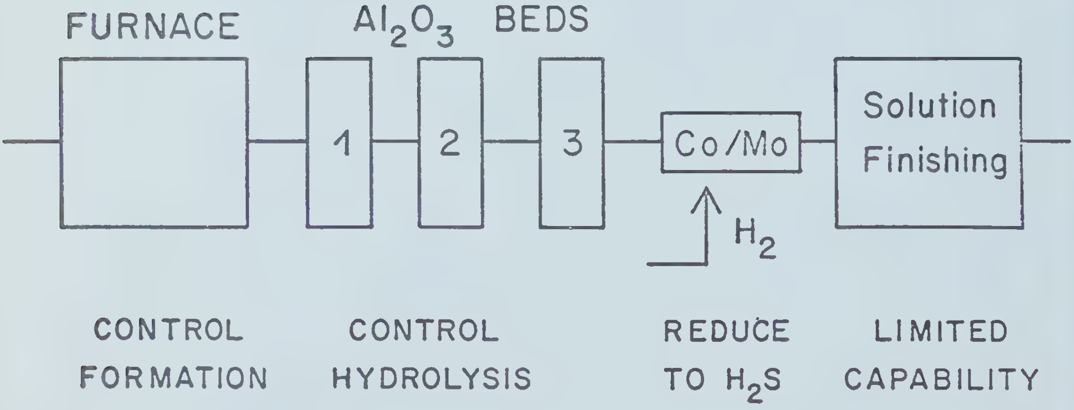


Figure VII - 2

new range of factors considered to be of importance in determining front-end reaction furnace performance.(3)

Some of the more critical elements of this study are summarized graphically in Figure VII-3. Of obvious importance in any chemical reaction is the efficiency with which the components are mixed. Considering the enormous volumes of gas fed through the reaction furnaces and the velocity that must be maintained, mixing is not as simple a matter as it might at first appear. Injection nozzle design has been and is still a primary aspect of industry's current research effort. A number of major operators, in collaboration with plant engineering companies, have continued to experiment with new techniques for achieving better mixing of the furnace feed streams. The traditional concentric axial flow nozzle design has been modified to include various forms of baffles, vanes and deflecting plugs all directed toward improved mixing efficiency within the combustion zone of the furnace. The effect of varying relative velocities of the fuel and air feeds to the furnace have been examined and tangential injection rather than axial feed of the air supply has been investigated. Vortex type burners and multiple injection ports of various designs are also being examined.

All of these variations in fuel/air injection techniques must be such as to maintain the critical H_2S/SO_2 ratio required downstream in the Claus catalytic section of the plant. As a result of these preliminary tests the industry and the furnace designers and manufacturers are becoming increasingly aware of the importance of the injection configuration in optimizing front-end reaction furnace performance.

FURNACE COMPONENTS

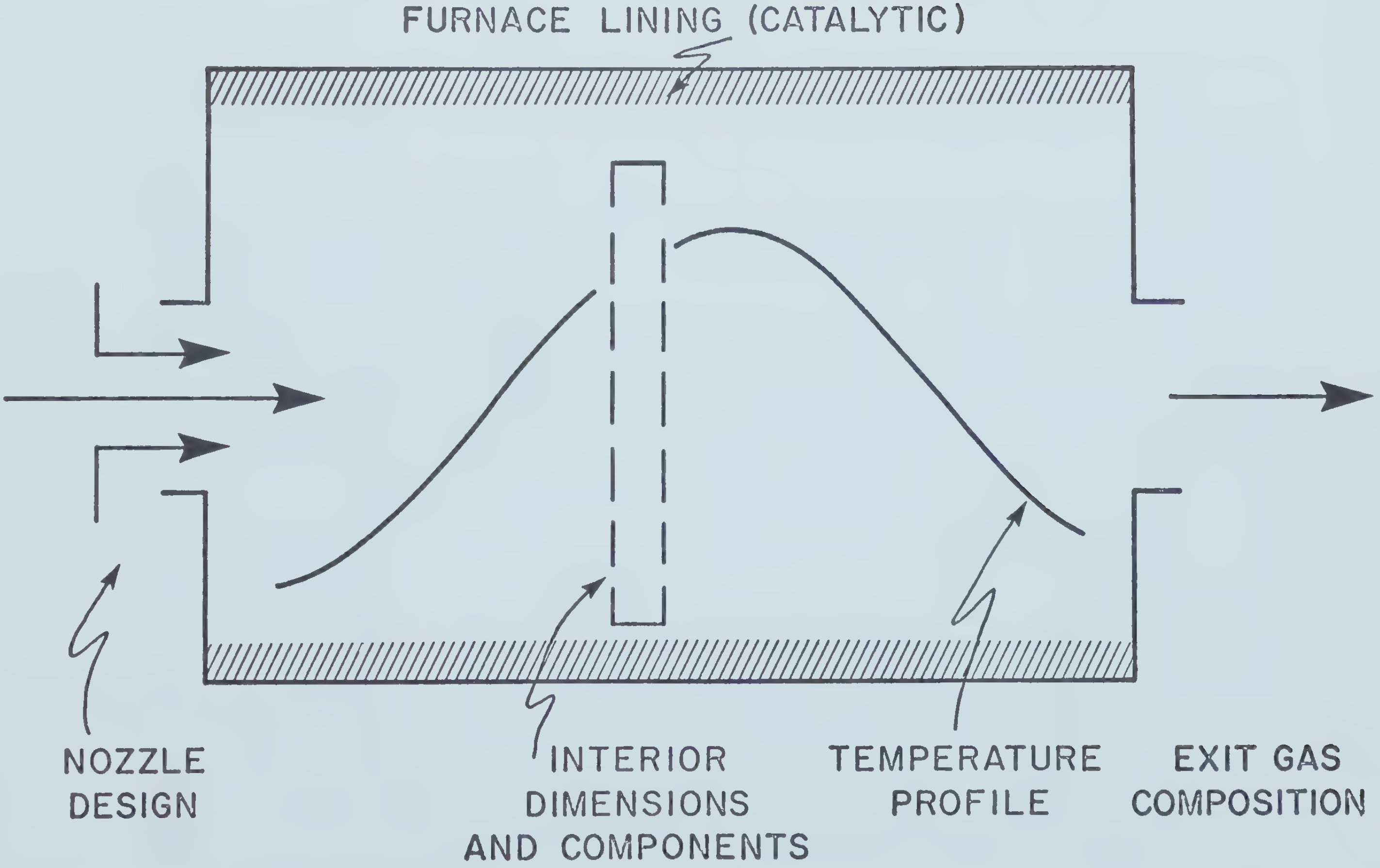

FURNACE LINING (CATALYTIC)
NOZZLE DESIGN
INTERIOR DIMENSIONS AND COMPONENTS
TEMPERATURE PROFILE
EXIT GAS COMPOSITION

Figure VII

A major factor determining reaction furnace performance is the temperature profile within the reaction zone and the residence time of the reactants in that zone. Injection nozzle design discussed above is of considerable importance here, but the interior dimensions and components of the furnace are equally critical. In particular the industry has recently placed more emphasis on an examination of the precise role of internal baffles or so called "chequered walls" on reaction furnace efficiency(4). It is already evident that the location of these internal components along the furnace axis has a marked effect on the relative importance of the mixing role as opposed to the effect on temperature homogeneity within the furnace. A number of plants are already making use of the results of these studies by incorporating suggested modifications in their furnace design on an experimental basis in new installations or in older units during plant turn around.

Variations and improvements in nozzle design or interior dimensions and components are primarily of value if they result in improved conversion efficiencies. This in turn is the result of closer approach to equilibrium conditions within the reaction zone. In view of the flow reactor nature of the furnace the speed at which these chemical reactions take place relative to the flow velocity of the reactants (i.e. residence time) is also crucial. The speed of these chemical reactions can be influenced by catalysts and an examination of the possible catalytic role of furnace lining materials represents a further area of current enquiry by the industry(5)(6). Work with so-called "wall-less" reactors has clearly shown that the catalytic role of the wall material may be a significant factor in determining furnace efficiency. While such catalytic effects on the type of reaction shown in Table VII-1 will clearly be of importance in determining sulphur conversion efficiency similar catalytic effects may also be operative in the side reactions of the type shown in Figure VII-2. Minimization of COS and CS_2 formation or, conversely, maximization of their decomposition by catalytic enhancement of the appropriate reaction speeds in the flowing system would be of very considerable benefit in reducing this form of sulphur content in tail gas. Also of importance is the catalytic effect on the rates of reactions producing such other "side products" as hydrogen and sulphur trioxide. The former, as will be seen later, is a valuable component of tail gas streams in some processes that require hydrogen to remove COS and CS_2. The latter is the principal source of sulphation of the Claus converter bed catalyst, a phenomena which results in reduced efficiency of this down stream section of the sulphur plant system.

Perhaps one of the great challenges facing science in the 70's is the problem of putting the results of a quarter century of elegant and sophisticated fundamental research to work for the benefit of thosewho have, in many instances, paid a sizeable part of the cost. This comment is particularly appropriate in relation to the gas processing industry's present efforts to apply the wealth of available fundamental combustion research knowledge to the improvement of front-end reaction furnace performance. Yet bridging the gap between the availibility of fundamental information and the translation into a practical manifestation in the form of improved industrial unit performance is no less difficult a task than that of acquiring the basic knowledge in the first place. The industry's responsible attitude to the need for continued improvement in its operation is well illustrated by its ongoing research and testing of front-end reaction furnace phenomena.

3. Claus Catalytic Converters

a. General

In recent years improvements in this section of the overall sulphur plant system are generally regarded as having been the most significant. Modifications have been introduced in both the design of the catalyst beds and in the nature of the catalyst itself. Both have led to higher conversion efficiencies and longer catalyst life. The problem of catalyst sulphation and consequent loss of activity remains a major unresolved difficulty although the current twofold attack through minimizing sulphur trioxide formation in the front-end reaction funace and change in catalyst manufacturing techniques may provice a solution.

Research investigation of the precise role of alumina based catalysts in the reaction of hydrogen sulphide with sulphur dioxide (the Claus reaction) has been active in both Alberta and elsewhere in Canada (7)(8). These investigations and companion studies of the fundamental aspects of gas phase heterogenous catalysis in related systems are essential to the further improvement of catalysts now in plant use and the design of new catalysts with even higher activities. Until the precise nature of the H_2S/SO_2 reaction at the catalyst surface is clearly understood optimization of the catalyst role will not be possible. New techniques such as total reflectance infrared spectroscopy and scanning electron microscopy have provided the researcher with valuable new tools for the examination of surface phenomena. It is this continuing research endeavour conducted both by industry and academia that has made possible the improvements of the past decade and that will lay the foundation for further improvements in the future.

b. New Catalysts

Alumina, Al_2O_3, in various forms remains the basis of virtually all Claus catalysts. Cobalt-molybdenum based material have recently received increased attention, but usually in specialty roles within the overall Claus system. Major catalyst producers are presently in the process of introducing new generations of catalysts which, it is claimed, will provide plant operators with improved catalyst performance. One such catalyst is claimed to have markedly improved porosity with better pore homogeneity providing higher space velocity characteristics in the catalyst bed. Absorption capability for SO_2 is considered to be the highest of any alumina and COS and CS_2 levels in the tail gas from such beds remains low for up to six months after initial charging.

Another "new generation" alumina based catalyst is claimed to have markedly improved resistance to sulphation deactivation and does not catalyze hydrocarbon polmerisation- a major cause of catalyst carbonation deactivation. Even after full sulphation this catalyst is claimed to retain good catalytic properties for carbon disulphide and carbonyl sulphide hydrolysis - an important method of reducing the concentration of these components in the tail gas.

These developments in catalyst manufacture have not

Equilibrium Conversion of H_2S to S

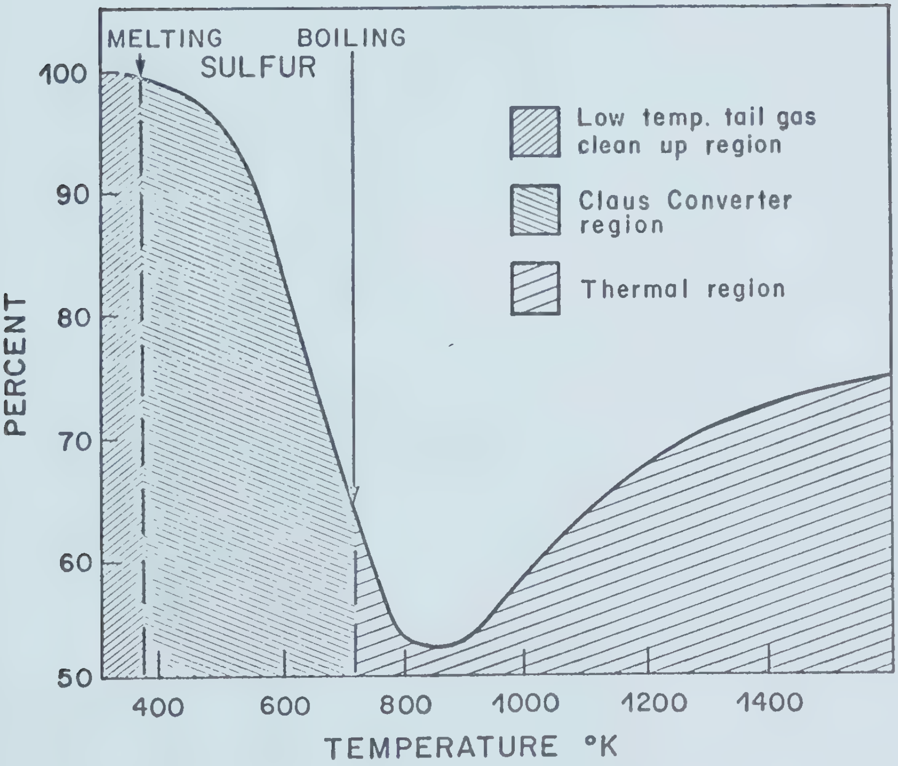


Figure VII- 4

Sulfur Recovery vs. Ratio

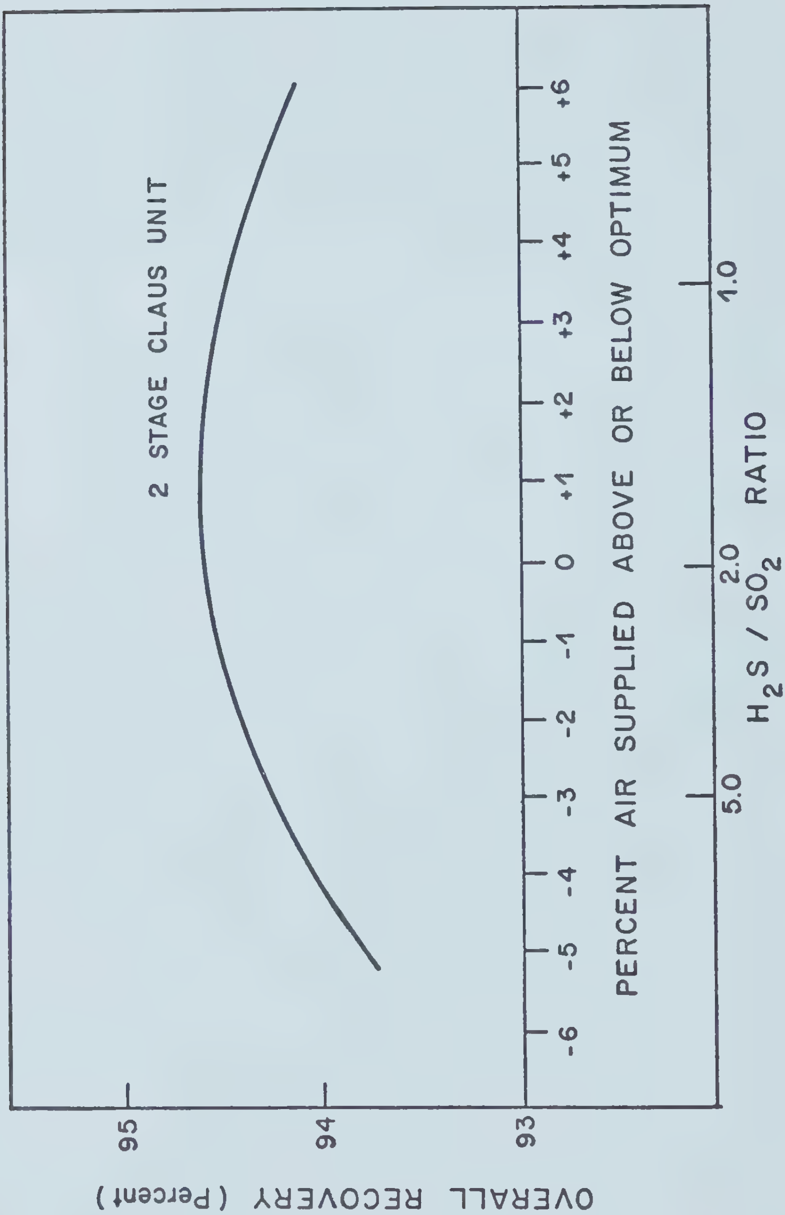


Figure VII-5

yet had an adequate opportunity to make themselves felt in the gas processing industry. If the claims are substantiated under practical operating conditions they will represent an important and welcome contribution to the continuing effort to improve plant conversion efficiency. Such improvements, taken alone, would not be sufficient to meet the new emission level requirements. Combined with better front-end reaction furnace performance, however, they may well enable smaller plants to meet present regulations without extensive and expensive add-on tail gas clean-up units.

c. Ratio Control

The conversion of hydrogen sulphide to sulphur proceeds not to 100% completion, but rather to an equilibrium condition where both reactants and products are present. The dependence of this overall conversion equilibrium on temperature is summarized in Figure VII-4. In the particular case of the Claus catalytic conversion equilibrium

$$2\ H_2S + SO_2 \rightleftharpoons 2\ H_2O + 3\ S$$

the position attained depends on a number of factors most important of which are temperature and relative concentration of the components (Figure VII-5). The equilibrium indicated above is a very simplified version, but serves to illustrate the point to be discussed here. The problem of maintaining the optimum H_2S/SO_2 ratio required for the Claus reaction has been one of the industry's principle concerns in recent years. Important though the ratio control is in the main Claus catalytic converters it becomes a crucial factor for tail gas clean-up processes that are themselves based on the Claus type reaction. Much effort has gone into the development of on-line analytical devices which continuously or intermitently determine the H_2S/SO_2 ratio downstream and feed back detected "off-balance" information to the front-end reaction furnace feed control where the ratio of H_2S to air can be adjusted to bring the downstream H_2S/SO_2 ratio back to optimum. The gas processing industry has greatly increased its in-line analytical monitoring over the past few years and specially designed spectroscopic and chromatographic analytical systems have been developed. In-line analysis feeding to front-end ratio controllers has done much to improve sulphur plant operating efficiency and further sophistication of this type of feed-back optimization will undoubtedly occur in the attempt to reach higher and higher conversion efficiencies.

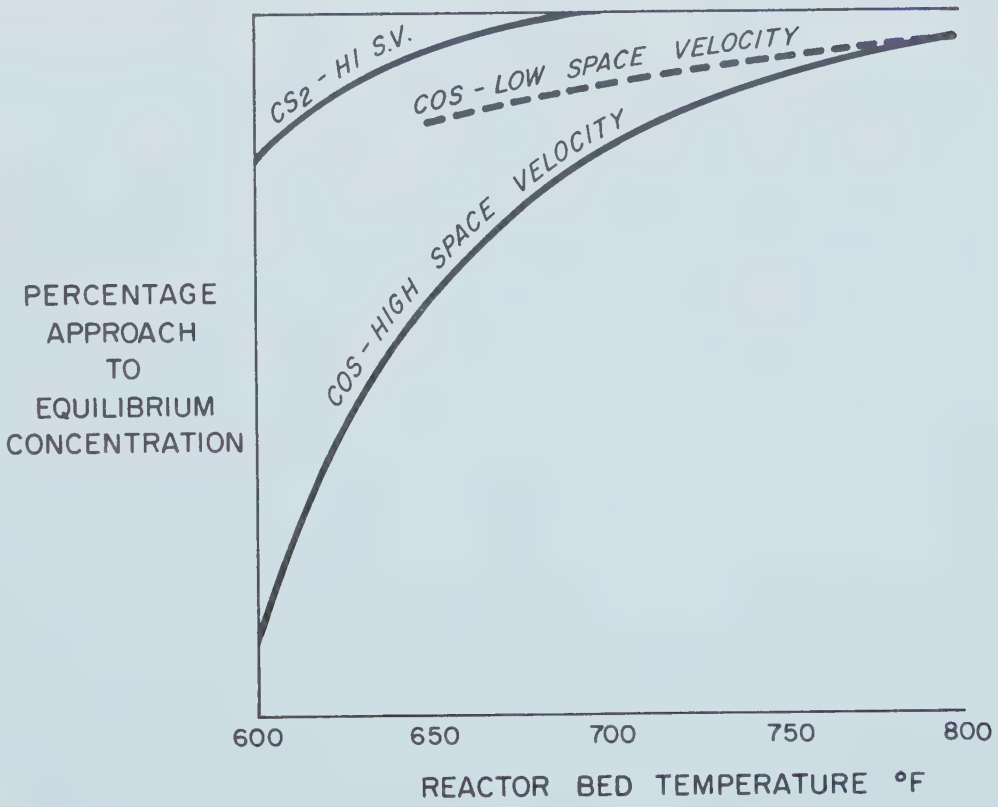
d. The Temperature Factor

As indicated in Figure VII-4, lower temperatures favour the products in the Claus reaction equilibrium. Reaction rates are slower at lower temperatures, however, requiring longer residence times or lower reactant flow rates to achieve equilibrium conditions. At lower temperatures below the sulphur dew point sulphur deposition on the catalyst becomes a serious problem and although this can be overcome by "regenerating" the catalyst bed with hot gases as is done in one currently available tail gas clean-up process, it requires multiple reactors alternately operating in service and regeneration modes. While this type of operation may be feasible for handling the low sulphur content of tail gas, it is impractical for the main upstream Claus reactors which can handle up to 50% of the total sulphur load on the plant. Apart from the need to operate at temperatures above the sulphur dew point and with reaction rates sufficiently high to permit reasonable space velocities higher temperatures in the Claus catalytic converters also favour the hydrolysis of carbonyl sulphide and carbon disulphide as shown in Figure VII-6/ Reduction of COS and CS_2 levels in the tail gas minimizes the difficult task of their removal in any tail gas clean-up process. Ironically, therefore, the plant operator faces the dilemma of "running hot" to minimize COS and CS_2 but thereby losing Claus conversion efficiency and increasing H_2S/SO_2 content in the tail gas. The operating temperature problem is obviously a complex one and the final decision depends on a variety of factors many of which will be specifically characteristic of a particular plant. The knowledge and experience gained through operation of the largest concentration of Claus reactor capacity in the world has given Alberta gas processors an opportunity to lead the field in this area., Through its Associations and the trade literature the members of the industry have actively participated in exchange and coordination of this "know how" to ensure that the best methods of environmental protection are available to all those participating in the most important task of bringing Alberta's energy resources to the consumer.

B. TAIL GAS INCINERATION

The various factors which control the sulphur conversion efficiency in the upstream units of a typical Alberta sulphur plant have been identified. The extent to which these factors are interdependent and oft-times antagonistic to each other places a very definite upper limit on the economically practical conversion efficiency that can be achieved within the plant itself. Indeed, there are remarkably few large scale industrial process operations that consistently function at 95% efficiency or better. Yet the Alberta sour gas processor has already been required to attain and now exceed this figure. While

HYDROLYSIS OF COS AND CS_2



COURTESY PARSONS

Figure VII - 6

there will undoubtedly be further improvement of the in-plant efficiency it seems highly unlikely that the larger sulphur plants can reach the required 98-99% level without further treatment of plant tail gas to desulphurize before incineration.

The capacity of the environment to receive and disperse gaseous effluents and the effects of various concentrations of these emissions on plant and animal life will be the subject of other sections of this brief. Our concern here is to examine the problem of reducing the sulphur content of Claus plant tail gas to a level which, after incineration, will yield an effluent which conforms with regulatory body restrictions on such emissions.

As indicated in Figure VII-1 the principal components in a typical tail gas are nitrogen, water vapour, carbon dioxide, hydrogen sulphide and sulphur dioxide. Minor but frequently troublesome components are carbon disulphide and carbonyl sulphide with small quantities of entrained elemental sulphur usually in the form of a fine mist. Upon incineration all sulphur containing components are converted to sulphur dioxide and it is in this form that the unrecovered sulphur in the plant system is vented to atmosphere. This is also the form in which the bulk of the sulphur emitted in coal and oil cimbustion occurs. Much attention has been given to the development of methods of desulphurization stack gas containing sulphur dioxide and many of these are identified in the list of patented processes included in this section. Because of the much wider market for SO_2 removal processes many of these techniques have enjoyed wide publicity and extensive development and testing. Re-examination of Figure VII-1, however, will reveal that the process of incineration of a Claus plant tail gas merely compounds the important concentration problem by adding further diluents in the form of nitrogen, water vapour and carbon dioxide resulting from the combustion of the incinerator fuel. The 3% sulphur content now in the form of SO_2 is more highly diluted than was the original 3% in the tail gas in the form of H_2S, SO_2, COS, CS_2 and sulphur mist.

In short the tendency has been to approach the problem of reducing sour gas processing plant sulphur emissions by developing methods of desulphurization the tail gas rather than the stack gas. Nonetheless, the enormous research and development effort being expended on stack gas desulphurization technique that will offer more attractive economics than current tail gas clean-up methods.

C. TAIL GAS SULPHUR RECOVERY

1. Methods

What are these methods for removing the last few percent sulphur from the hot, dilute effluent gas streams? As the following list of process names indicates, they are, at the very least, numerous:

Aquaclaus
Beavon-Parsons
Bu Mines Citrate
Calsox
Cataban
Clean Air
Chiyoda
IFP
Sulfreen
Sulphoxide
Stretford
Vetrocoke
Wellman-Lord

The details of all of these processes have been extensively reviewed and no attempt is made here to examine them in detail (9)(10)(11). It is, however, pertinent to look at those tail gas clean-up processes which have reached a stage of development that permits reasonably accurate evaluation of their applicability in the Alberta scene.

The Sulfreen and IFP methods are currently in operation at Alberta plants. The former is essentially a low temperature Claus reaction utilizing the enhanced conversion equilibrium characteristic of lower temperature (see Figure VII-4) and operating on an alternating in service/ in regeneration cycle discussed earlier. Overall conversion efficiencies in excess of 98% are claimed for a combined Claus train and Sulfreen unit. Ultimate limit of clean-up is indicated to be 2000 ppm at the stack mouth. The IFP process, unlike the Sulfreen is a solution process, but again depends on the Claus reaction between H_2S and SO_2 for conversion of these gaseous components to elemental sulphur and water. Overall recoveries in excess of 99% are claimed with a combined 2-stage Claus plant and IFP solution process. Ultimate clean-up limit of the basic IFP process is comparable with Sulfreen. Neither process, however, has any inherant capability to handle COS and CS_2 in tail gas, thus the lower limit of clean-up cannot be less than the CS_2 + COS sulphur values.

The U.S. Bureau of Mines Citrate process and the Molten Carbonate process were primarily developed to handle sulphur dioxide removal from smelter effluents or fossil fuel combustion stack gas. The Bumines process has many chemical similarities with the IFP, but is an aqueous solution process operating at considerably lower temperatures. The Molten Carbonate system is of interest because it gives a good indication of the kind of techniques that may be characteristic of the next generation of clean-up processes - the whole technology of molten salts as solvents for industrial chemical reactions is in its infancy.

The Vetrocoke clean-up process is one that has been in use in Europe for some time and at least one plant in the U.S. has utilized the desulphurization technique. The process utilizes arsenic compounds and for that reason has been approached cautiously by operators concerned about the introduction of a secondary environmental contaminant in efforts to remove the primary one. More will be said later on this subject of replacing one pollutant by another!

The four remaining processes noted are all capable of reaching very low sulphur effluent levels. Two, the Beavon-Parsons and the Pritchard Cleanair, utilize the Stretford process in a common solution finishing step. Both have upstream stages where CS_2 and COS are catalytically reduced to H_2S since the Stretford process - like almost all other solution finishing processes - does not convert CS_2 or COS. Finally, the Wellman-Lord is not a conversion process at all, but rather a technique for reconcentrating the dilute SO_2 in incinerated tail gas for refeed into the front-end of the sulphur plant. In this respect it is a process which has wide applicability beyond sulphur plant effluent treatment and indeed, many of its current applications are as a clean-up system on systems other than Claus plants.

2. Economic Considerations

How do these various processes compare as far as efficiency and economy are concerned? That story is summarized in graphical form in Figure VII-7. As the sulphur level decreases the cost-factor increases - expotentially! There is often a tendancy to avoid or even

HOW CLEAN for WHAT COST

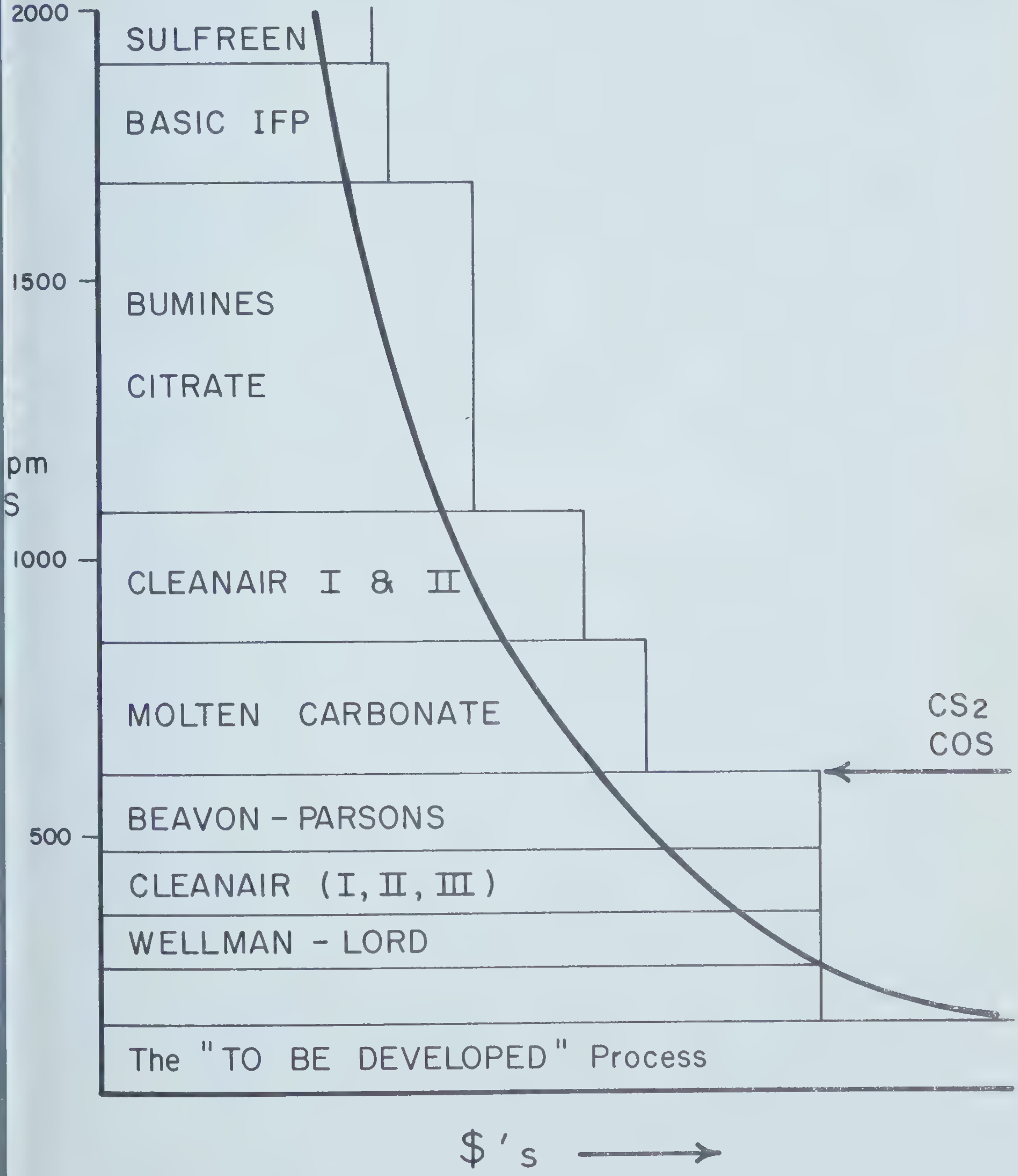


Figure VII - 7

deny the validity of cost considerations when considering environmental conservation. Those charged with bringing Alberta's vast resources to the market place, however, would be less than responsible if they were to ignore the costs of producing their product and hence establishing a fair market value(12). The quality of the environment will only be maintained if the price to the end use consumer is kept at an acceptable level. The major influence of these cost/benefit considerations of tail gas clean-up methods will be in identifying those techniques which can be most easily and most economically incorporated into existing systems. In the long term, radical new technologies may lead to entirely different process systems, but current capital investment in sour gas processing equipment is such that for a number of years "add-on" improvements such as those discussed above will be those under consideration.

Virtually all of the clean-up processes identified in Figure VII-7 have a common feature. Their cost increases almost linearly with the load placed upon them. That is, for any given process required to attain say, 99% desulphurization, the cost of an installation to handle a 5% sulphur content tail gas stream will be approximately twice that of a 2.5% sulphur containing tail gas. This is particularly true of the solution processes where ability to handle a given sulphur loading is directly related to solution pumping capacity. This linear relationship between clean-up cost and sulphur loading is perhaps one of the greatest incentives to the industry to obtain every possible percentage point of efficiency out of the upstream units of the sulphur plant. Whether it be in the front-end reaction furnace or in the Claus catalytic converters every extra percent of conversion extracted there means that much less installed clean-up capacity of the tail gas.

Figure VII-7 also illustrates what might be regarded as a minimum cut-off for certain of the clean-up processes currently available. Rarely, under present operating procedures, does a sulphur plant in Alberta have less than 600 ppm COS and CS_2 in its tail gas. Accordingly, for those processes lacking the capability to convert COS and CS_2, this must be a lower limit. Many plants, however, have much higher CS_2 and COS levels in the tail gas and clearly these levels will be the limit of clean-up capability, irrespective of H_2S and SO_2 removal efficiency of processes that do not handle COS and CS_2. The capital cost for full compliance with recent regulation has been estimated at between $30-40 million. Another figure which incorporates operating costs of tail gas clean-up units needed to meet present requirements is $25,000 to $35,000 per ton/day of sulphur produced by these units.

There is no doubt that enhanced sulphur recovery in the 99% range will not be economically viable. The "benefit" is environmental protection. Table VII-2 tells the story of the value of sulphur on world markets over the period in which Alberta has become a major producer. The 1970/1980 comparison of effluent production and consumption makes it abundantly clear that as we strive to reduce the level of sulphur emitted to the environment by enhanced recovery, sulphur production will continue to move ahead of consumption growth with a resulting increase in the excess of supply over demand. Development of major new large tonnage uses for sulphur, may reverse the build up of sulphur inventory, but these new uses are not yet in sight. The cost of reaching into the 99% recovery efficiency bracket must then be viewed as a direct and undiluted cost against the product of the sour gas industry that is in great demand - methane, the clean , calorific pipelineable product that more and more provides the energy

THE RISE AND FALL OF SULPHUR PRICES

YEAR	PRODUCTION (TONS)	SALES (TONS)	SALES VALUE ($000)	PRICE PER TON ($)
1971	4,500,000	2,800,000	21,000	7.50
1970	4,241,616	3,122,973	27,871	8.92
1969	3,714,120	2,619,246	60,018	22.90
1968	3,042,890	2,260,250	78,050	34.53
1967	2,168,604	2,188,645	66,557	30.40
1966	1,729,454	1,799,550	38,769	21.54
1965	1,589,586	1,818,104	25,235	13.87
1960	403,516	241,411	4,844	20.06

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Table VII -

demanded by those who enjoy the environment we struggle to protect.

Present requirements for clean-up do not exceed 99% or 10,000 ppm (1%) in the vented effluent. Bearing in mind the exponential cost increase with decreasing level of sulphur content in the effluent as demonstrated in Figure VII-7, some straightforward arithmetic suggests a figure of half a billion dollars may not be an unreasonable estimate of the cost of reaching 1000 ppm.

If half a billion dollars is the price of no inconvenience - and we have no assurance that even 1000 ppm effluent will provide that - would the improvement be worth the cost. What other benefits to society could be introduced for this cost? The cost, we should not forget will be borne by society directly or indirectly. Since the decision to proceed to yet lower emission limits will be made by government in the form of its regulations, government must consider its priorities and the justification for asking society to pay half a billion dollars not to remove a hazard, but to reduce an inconvenience.

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VIII COMMENTS ON ATMOSPHERIC SULPHUR DIOXIDE

Sulphur dioxide is one of the most misunderstood of the gases contained in the earth's atmosphere. On the one hand we know that sulphur is essential to life and that the greater part of our requirement is supplied from atmospheric sulphur dioxide. On the other hand we know that SO_2 can be harmful and can cause severe respiratory problems, and in cases of extreme exposure can result in unconsciousness and death from suffocation. The question of whether sulphur dioxide is beneficial or detrimental hinges on the concentration of the sulphur dioxide in the environment.

It is not generally recognized that there is a sulphur dioxide cycle in the atmosphere much like the well-known carbon dioxide cycle. It is estimated by the Stanford Research Institute(1) that about 220 million tons per year of sulphur are introduced into the atmosphere, and a similar amount is removed therefrom. The chief sources are decaying organic matter, sea spray, and man-made pollutant emissions. Natural sources account for about 2/3 of the total while man accounts for about 1/3. Of the total man-made emission, 70% is estimated as resulting from coal combustion and 16% from the combustion of petroleum products, mostly residual fuel oil. The remaining amount is accounted for by petroleum refining operations and by non-ferrous smelting. Thus out of the total anthropogenic sulphur dioxide only a very small part comes from gas processing. As a point of interest, it is estimated that about 750 tons per day of sulphur are generated by the sulphur plants spread throughout Alberta, while over 3500 tons per day are emitted at one location in Ontario, i.e. Sudbury(2). There is another significant factor in Alberta in that neither coal nor fuel oil are extensively burned in the province and these sources of SO_2 are almost nonexistent here. The demands of Alberta industry on the atmosphere to absorb SO_2 are comparatively small.

Sulphur dioxide, then, in low concentration is a natural and essential component of the atmosphere. What is not generally realized is the fact that vegetation, which is the source of new protein, requires nearly the same amount of sulphur as phosphorus for satisfactory growth. Plants obtain sulphur they need by direct absorption of SO_2 from the air, by the absorption of sulphates which have been deposited in the soils by precipitation, and from the addition of fertilizers. Although, as previously noted, coastal areas receive sulphur from rain contaminated with ocean spray, inland continental areas are dependent on the gases in the atmosphere and man's supplementation of them. Many areas of the world are deficient in sulphur. These include 30 states in the United States, 5 Canadian provinces, and areas of Western Europe, Latin America, Australia, New Zealand and Asia. When sulphur-containing fertilizers are applied to crops deficient in sulphur, the responses are often dramatic. Crop yield increases of 1000% or more have been reported. A study of the consumption of plant nutrient in North America indicates a potential use of about 2.8 million long tons of sulphur annually in the United States and Canada(3). Dr. D. R. Walker of the Canada Department of Agriculture Research Station at Lacombe, Alberta has examined the relationship between sulphur oxide emissions into the atmosphere and the sulphur content of Alberta soils.(4) He found that sulphur requirements for various crops were as follows:

Cereals - 4 - 5 pounds - per acre
Legumes - 8 -10 pounds - per acre
Grasses - 6 - 8 pounds - per acre
Rapeseed - 10 -20 pounds - per acre

Studies have shown that a sulphur deficiency exists in 1/2 - 2/3 of the gray wooded soils of Central and Northern Alberta. The emissions from sulphur plants in Central Alberta were examined and it was found that the annual deposition of sulphur was 2 - 4 pounds per acre. Since a portion of this is lost in surface run-off, the amount of sulphur available to plants will only be part of the total requirement. Dr. Walker concluded that "The present levels of sulphur oxides in the atmosphere in Central Alberta would seem to be contributing insufficient sulphur to the soils of the area to eliminate the sulphur deficiency that exists, except perhaps where the deficiency is marginal."

Concern is occasionally expressed regarding the oxidation of SO_2 to SO_3 in sunlight and the subsequent combination with water to form H_2SO_4 aerosols. Dr. Linzon(2) of the Ontario Department of the Environment states that the rate of photooxidation is between 0.1% and 0.2% per hour. It is more rapid where hydrocarbons and nitrogen oxides are present, which could be the case within the plume of the sulphur stacks. In any case the size of the aerosol droplet is stated by Robinson and Robbins(1) to average about 1 micron, or 1/1000 of a millimeter. These droplets are so small as to stay suspended in the air, until removed by some mechanism such as precipitation, and they are so thoroughly dispersed as to be insignificant in effect. It has been shown that even when in an experiment the droplets formed a mist so dense that visibility was reduced to 3 feet, they failed to produce injury to alfalfa and sugar beets. It has been determined that of the total mass of sulphur compounds in the atmosphere, 65% is in the aerosol form. Thus the formation of H_2SO_4 aerosols is a normal atmospheric phenomenon and is not considered harmful in normal concentrations.

A study of sulphate in Alberta precipitation was made by Summers and Hitchon(5) of the Research Council of Alberta because of two observations. The first was that soil scientists had noted a decrease in the sulphur deficiency of some Alberta soils. The second was the marked reduction of hail activity in Central Alberta since 1961 and at the same time an increase in the number of reports of soft hail. The study determined that, in the summer months, a considerable fraction of the SO_2 from a particular sulphur plant was oxidized and deposited as sulphate within a radius of 25 miles of the plant. However, in the winter months they state that the SO_2 travels a longer distance from the source before being removed from the atmosphere. Robinson and Robbins estimate the life of sulphur dioxide in the atmosphere to be 4 days. Since the air circulates in a local concentric pattern and the systems move across the continent at a relatively slow rate of speed it is probable that there will be substantial removal of SO_2 in the winter within Alberta, with additional deposition in Saskatchewan and Manitoba. The important consideration here is that in the growing season the sulphur emissions from Alberta gas plants are deposited within Alberta and utilized by crop vegetation. The emissions are not wasted and they should contribute little to the general background level of SO_2 in the world atmosphere inasmuch as they are deposited and utilized in the same general area where they are generated.

A reduction in sulphur emissions resulting from increased sulphur plant recovery requirements will actually contribute to sulphur deficiencies in the soil, at the same time increasing the sulphur which will be stockpiled and will be useless for the foreseeable future. To quote Jan Platou(3) of the Sulphur Institute of Washington, D. C., "We are thus faced with the paradox that some of the sulphur we take out of the stack will have to be put into fertilizers to get it back into the soil, where it would have ended up if we had not taken it out of the stack in the first place."

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EPILOGUE

The Canadian Petroleum Association presents the following matters for consideration by the Environment Conservation Authority before final recommendations are made to the Minister of the Department of the Environment.

1. The related and respective roles of the Department of the Environment and the Energy Resources Conservation Board should be clearly defined by government policy statement. The Department of the Environment should set the environmental standards for the petroleum industry and the Energy Resources Conservation Board should administer them.

2. It was unfortunate that no direct input to the hearings was forthcoming from any government agency or department other than through the Klemm report. Relevant government statements for public purview would be of considerable interest, and useful to the Authority.

3. Non-energy mineral resource recovery efficiencies are not normally specified by government regulation. Sulphur is not an energy resource and within this principal parameter we question the wisdom of the Energy Resources Conservation Board involving itself in production and recovery efficiencies.

4. The limitation and monitoring of 'total sulphur' emissions from the stack of a sulphur extracting facility are considered acceptable practices required of the industry, and are used in the sulphur balance and plant material balance calculations.

5. 'Total sulphur' stack emission limitations (tons S_2) should be clearly separated from sulphur stack emission concentrations (ppm SO_2).

   Beyond the 'total sulphur' stack emission limitations, which primarily perform a conservation function, and a coincident role in limiting pollution capability, the only meaningful measurement related to environmental conservation is the concentration of the relevant effluent at ground level, and comparing that to the prevailing ambient air quality standard.

6. The intensity or sophistication of any particular monitoring program should only be based on the need to meet such uncertainties as may be uniquely observed, and then applied within the existing general standards.

   Industry has enjoyed the opportunity in the past to negotiate its uniqueness for a particular application before the appropriate government agency and within the existing standards and regulations, having due regard for all the pertinent scientific, technical, and other facts. The continuation of this policy should be confirmed.

7. Such research projects as were mentioned during the hearings represent only a portion of the total research effort of the industry.

We recognize the possible need for joint industry/government research projects, particularly as they may relate to areas of mutual interest and public concern and therefore recommend the establishment of an industry/government task force to review joint research possibilities, at an early date.

The results of any jointly-funded research may provide the type of scientific and technical input required to substantiate existing or proposed legislation.

8. Finally, we wish to reiterate the industry's willingness to join with any governmental agency in discussing the possible establishment of new guidelines, regulations or standards.

We hope that no new guidelines or changes in standards will be established unilaterally by government. This would avoid the imposition of any sudden demands on the industry without sufficient lead time to assess any new situation or defend the status quo as may be deemed appropriate by industry, based on good, supportable, practical common sense and scientific evidence.

Calgary, December 6, 1972

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

The first question I would like to ask is in reference to a point made in 1-3 which says that the East Crossfield Plant is still paying out the original investment after four years. I would like to have some assessment of how long the investor would expect to incur a payout on his initial investment.

MR. D. SWANTON

Well, I believe every gas plant operator has his own economic criteria; the company I work for uses as a rough guide a return on investment of 10 percent which would equate payout of approximately 10 years.

DR. S.B. SMITH

I'm not too sure that I understood the reference. Does this mean that the East Crossfield Plant was only paying back on investment and that there was no profit? To what is the reference directed?

MR. D. SWANTON

The problem at these Crossfield Plants specifically is that a major part of the revenue was anticipated to come from the sale of sulphur, and the prices of sulphur have declined considerably since this plant was constructed.

DR. S.B. SMITH

That leads me quite naturally to the next question, because this is what I was really trying to get at. Mr. Chalmers pointed out that they have an extremely high recovery rate for sulphur and that the original design perhaps accounted for this original high rate of recovery. Would it be then that the attractive economic condition to some extent dictates the design of the plant?

MR. D. SWANTON

No, we have to recover the sulphur if it's in the gas that is fed to the plant. I suppose we regard sulphur as an involuntary production. It has to be produced if you wish to produce the gas.

DR. S.B. SMITH

The fact that the Balzac Plant, for instance, exceeds the demands placed on it by regulation is not initially connected ten years ago with the very high pressure sulphur......

MR. D. SWANTON

Relative to the price now? That's a pointed question! I'd have to say that sulphur plants in general have an easy recovery level to obtain; we have tossed around the number of 90 to 95 percent. Once you have passed this recovery level, we start to incur greater and greater investment, and I think right now the levels of sulphur recovery we are obtaining are set there because of regulations rather than price; I don't think you could substantiate the increased recovery of sulphur as an economic venture.

DR. S.B. SMITH

Perhaps I could conclude this question on this chapter by asking whether initially the design criteria could be very stringent indeed, and then as the price of sulphur falls, the emissions become a little more noxious and then gradually regulations rather than economics take over. Is this a reasonable approximation of the situation over the last ten to twelve years?

MR. D. SWANTON

I think a better approximation of the situation would have been that if we could have foreseen the decrease in sulphur prices we might have reconsidered development of this field.

MR. W.A. FLOOK

There was a slide placed on the screen which indicated that the total investment for the industry was $600 million. It was listed under 'Benefits to Alberta' and the inference was that the $600 million dollars was a direct benefit to Alberta. Would you care to elaborate a little bit on this, and perhaps indicate how much of that $600 million was indeed spent in Alberta?

MR. D. SWANTON

We don't really keep accurate data on what is spent in Alberta. I know that, with the increasing emphasis on Canadian content, even though the plants are constructed by international contractors we make it a point to maximize Canadian investment. Now, in our particular instance this means Alberta investment. Virtually all the labor is Albertan, a lot of the small sub-contractors are Albertan, a lot of the smaller-size projects are done by contractors which reside and have either head offices in Alberta, or branch offices in Alberta. We make every effort to maximize Canadian content.

MR. W.A. FLOOK

Yes, I realize this of course, but when such a statement is made, on face value it gives a certain impression and I am just trying to find out what your opinion is of just how valid that impression might be. Would you say that about half of that amount of money directly accrued to people in Alberta, or less than half?

MR. D. SWANTON

Let's say it would be definitely more than one-quarter of that and would probably approach a half. I would say that would be a fair estimate.

MR. W.A. FLOOK

So a more appropriate figure would be probably $300 million?

MR. D. SWANTON

For a direct investment in gas plants.....

MR. W.A. FLOOK

Of direct benefit to Alberta.

DR. W.R. TROST

I would like to refer you to Figure 1-1, on which there are four curves drawn. Two of the curves seem inclined to reach heaven and the others are inclined to level off; can you explain the differences between these two sets of curves -- the flattening out ones and the ascending one?

MR. D. SWANTON

I didn't study this figure particularly carefully, but I would say that those that increase in the sulphur production capacity of the province have probably been attributed to the major construction projects we have had over the last three years. Three that come to mind to myself are the Kaybobs 1, 2 and 3.

DR. W.R. TROST

So there is no justification in extrapolating those any further than they are presented on the graph. They may take another stepwise move later on -- is that what I understand?

MR. D. SWANTON

This may be just a short-term phenomenon. I think a broader overview of this would be on the recoverable sulphur reserves of Alberta detailed later on, which show a lessening rate of increase. Figure 1-11 is perhaps a better estimate of present and projected Alberta sulphur production. A longer term view would be based on the recoverable sulphur reserves in Alberta, which basically indicate that we can't go on forever expanding with a finite resource.

DR. W.R. TROST

It lies indeed in contrast with the other figures; I thought I would try to get clarification on this one.

MR. D. SWANTON

Another point too; the Figure 1-1 is also sulphur production capacity. There are a number of factors here. If you have an old plant you still have the same sulphur production capacity, even though your processing volumes are decreasing. You have extra capacity to take into consideration; you have days which you have to produce at maximum rates, whereas over the year you only have to produce at less than the capacity.

DR. W.R. TROST

Well, now, it seems to me that we're looking at three different figures, one of which shows sulphur production leveling off very sharply in the period of 1970 onward.

MR. D. SWANTON

Now that is sulphur reserves, I believe, which are a reflection of the continuing exploration effort in Alberta.

DR. W.R. TROST

It's labelled sulphur production.

MR. D. SWANTON

This is Figure 1-1 you're referring to?

DR. W.R. TROST

Yes.

MR. D. SWANTON

It takes a considerable period of time from the discovery of new reserves to the complete development of the field, and this may be a reflection of the fact that in the past couple of years there have not been any major new discoveries of sour gas.

DR. W.R. TROST

Still, the projected Alberta sulphur production does continue to rise so that in the 1980's it will be more than twice, almost thrice what it is now; to square that with the Figure 1-1 you would suggest that there are successive upward rising steps, or inclinations, to be assumed for the projected period.

MR. D. SWANTON

I personally regard that upward step in Figure 1-1 as an anomaly on the general trend.

DR. W.R. TROST

I am referring to the two curves: "Raw sour natural gas capacity" and "Sulphur production capacity" which are shown to level off at that period of time.

MR. D. SWANTON

That's true, but if you project that line, I'd call it a straight line with a hump in it and a leveling off; we don't have enough data to say where it's going to go.

DR. W.R. TROST

In other words, what I suggested to you you say is right; namely, that it will continue an upward trend subsequently.

MR. D. SWANTON

It will continue an upward trend, yes.

DR. W.R. TROST

Now, in your Figure 1-11 the upward trend that is consistent in a slightly wavy way beyond 1980 is still ascending.

MR. D. SWANTON

That's correct.

DR. W.R. TROST

But the projection from the Energy Resources Conservation Board is a projection that flattens off at about the same time. It's almost asymptotic at that time. How do you correlate those two slightly different figures?

MR. D. SWANTON

They both came from the Alberta Energy Resources COnservation Board. The other point which Howard made is that one is reserves, and the other is production. Now, the production may continue to go up, I would imagine, as new plants are brought on line; whereas you might expect for plants which are on line, which are continuing production at the same rate, the recoverable reserves left after that production would show a decrease.

DR. W.R. TROST

Yes, that's exactly what I thought was the explanation. How do you put these two figures together to give us an estimate for the life of these fields, the producing life of these fields?

MR. D. SWANTON

Each field is an entity in itself, and has its own production life. Under gas contracts in Alberta presently, it generally figures out that a project life from start of production to shut-down is about twenty-five years.

DR. W.R. TROST

Yes, but I return to the thought that you actually have given overall statistics that when put together do lead to an interpretation that may be an overall life, from the same overall statistics.

MR. D. SWANTON

What you're asking is what percentage of the ultimate recoverable reserves have we found in Alberta.

DR. W.R. TROST

I'm not really asking that; I'm just asking you to interpret from two sets of data that you have presented us that could lead to such interpretation. I'm not asking for anything new in either proffered material.

MR. D. SWANTON

I don't really think, without considerable thought on the matter, that I would like to give an answer on a long-term question like that right here.

DR. W.R. TROST

One can, nevertheless, put it in these terms. In Figure 1-11 you are projecting continually increasing sulphur production, even though over the same period of time you are also projecting a disappearance of new fields, as it were. - - a slowing down of the rate of recovery, right?

MR. D. SWANTON

No. We're projecting a decrease in the amount of sulphur left in the ground as we produce it, which is an indication that we're approaching a more mature stage of our resource development in Alberta.

DR. W.R. TROST

Do you think that's what you're actually doing?

MR. D. SWANTON

Well, I think that we have a finite resource in oil and gas in Alberta and sooner or later it has to run out. You might as well face that fact.

DR. W.R. TROST

Right. Now what do you mean by 'sooner or later'?

MR. D. SWANTON

When are we going to run out of oil and gas in Alberta? I really can't say.

DR. W.R. TROST

Are the oil and gas reserves, and the reserves of sour gas, in your view, to be handled in the same logic?

MR. D. SWANTON

Yes.

DR. W.R. TROST

So you really haven't, in the industry, any estimate for yourselves as to when your plant will have finished its task?

MR. D. SWANTON

I have not. We didn't concern ourselves with this problem in any depth for this submission.

DR. W.R. TROST

Do you design your plants individually for a life that will be related to the life of the reserves that are feeding the plant?

MR. D. SWANTON

That's true.

DR. W.R. TROST

Can you tell us from that point of view what kind of life expectancies may be associated with these developments?

MR. D. SWANTON

The life of an average gas field development is approximately twenty years.

DR. W.R. TROST

You had indicated that new plants being built that are not yet on stream presumably have similar lives, is that right?

MR. D. SWANTON

That's true. Basically the life of the plant is determined by the gas purchase contract which you can obtain, which in the future let's hope is going to be directly related to the scarcity of gas.

DR. W.R. TROST

Returning to a subject that may perhaps be related to this -- and I'm not quite sure that you fully answered Dr. Smith's questions on the economics of it -- do the costs of sulphur recovery in any way affect the rate at which sour gas might be sold and consequently bear on the question of the life of the plant and the life of the reserve?

MR. D. SWANTON

Basically, plants are sized on the gas through-put volume, which is the residue sales gas volumes. The attendant sulphur production problems, you have to accept. Plants are sized on gas through-put, not on sulphur production volumes.

DR. W.R. TROST

So, in essence, your answer is that the economics of the sulphur extraction part of the process don't bear on the sale of the gas, the rate at which it's sold, or the marketability of the gas.

MR. D. SWANTON

This is an overall bundle. We're looking at economics of a project. We can't really break it down and say it would be economic to produce it if we didn't have to produce sulphur. It's a complete package, and the development of an area concerns itself with the complete investment and the complete revenues that you're going to accrue from that project.

DR. W.R. TROST

Is the answer to my question then 'yes'? Do the economics of extracting sulphur from the sour gas have any bearing on its marketability, and hence on the life of the plant that you're designing for it in terms of years, and the length of time that those reserves may be used?

MR. SWANTON

If you pose your question as four particular parts I could probably answer you "yes" or "no" to each particular part.

DR. W.R. TROST

Maybe we better go to another part of the question, and we can, perhaps, question someone else on this matter.

MR. J.E. BAUGH

Once you continue with Mr. Swanton, we do have something to add with respect to the question of sulphur reserves and production rates.

DR. W.R. TROST

In discussing the industry's safe operating practices, and here we're dealing with materials that have their problems, where have you in practice experienced the greatest difficulty and risk, in terms of safety?

MR. D. SWANTON

The item that stands out in my mind is the problem with H_2S, which is a toxic gas in low concentrations. And I think this is the area where we have most serious accidents.

DR. W.R. TROST

How serious have the accidents been?

MR. D. SWANTON

People have been killed in gas plants.

DR. W.R. TROST

And in drilling operations, have fatalities occurred?

MR. D. SWANTON

I believe that's true.

DR. W.R. TROST

So that, as a result of accidents, one is exposed to serious risk?

MR. D. SWANTON

There is a high potential hazard in the operation of sour gas facilities. I think, though, to keep these in perspective we have to examine the success the industry has had in recognizing these hazards and in controlling them.

DR. W.R. TROST

Right. Now, in respect to these kinds of incidents that have led to serious episodes, as you've described them -- some of them presumably occurring in the plant -- are any of these of recent origin or are these from a longer time past?

MR. D. SWANTON

Safety is a continuing problem in gas plants; there are going to be continuing hazards and there are going to be continuing accidents. We make every effort to keep them to a minimum, an absolute minimum.

DR. W.R. TROST

In respect to sulphur storage and transportation, are you in a position to comment on the problem that the industry is now faced with in the requirement that it stockpile a good deal of its output?

MR. D. SWANTON

I think it's just a cost associated with the production.

DR. W.R. TROST

And how would you calculate that?

MR. D. SWANTON

It's the cost of land, the cost of making those facilities available, the cost of taking the sulphur out of block whenever you have a market for it.

DR. W.R. TROST

And, can you make any kind of a quantitative expression of those costs in a stockpiling operation?

MR. D. SWANTON

Well, it depends on scale; if you have a larger scale plant and you have a large sale, you can come in and move your sulphur at an economic rate. I believe the costs of stockpiling sulphur are about twenty-five cents a ton, and the costs of removing it from the block are anywhere from seventy-five cents to two dollars a ton. That is, sulphur in a block.

DR. W.R. TROST

So you're exposed to extra costs of handling as well as what might be called keeping capital in reserve in some way?

MR. SWANTON

Right. This is one of the reasons behind the unit train concept and the shipping of sulphur from limited points in the province. We try and keep all our live storage at a minimum number of plants, which reduces our storage costs.

DR. W.R. TROST

In Figure 1-12 you show the free world production and consumption of sulphur.

MR. D. SWANTON

And the production from Canadian plants, which is primarily Alberta's, is shown in Figure 1-9.

DR. W.R. TROST

Now the interpretation to make from Figure 1-9, I suppose, is that we're producing quite a lot of sulphur, right?

MR. D. SWANTON

That's right.

DR. W.R. TROST

But -- and again this is why I tried to get some clarification from you earlier as to the probable time that this condition would prevail -- in 1970 it seems to me that Canada is producing more .... maybe we can refer over to Figure 1-11 -- Canada is producing something like 9 million long tons....

MR. D. SWANTON

That's cumulative; 9 million long tons is a total of U.S.A., France and Canada .....

DR. W.R. TROST

And Canada's share of that is about 6 million, is it?

MR. D. SWANTON

I hope it's four and a half.

DR. W.R. TROST

So you would suggest that Canada is doing about half of that?

MR. D. SWANTON

That's what it looks like.

DR. W.R. TROST

The total free world production was something under 30 million, so we're doing something like 15 percent.

MR. D. SWANTON

I believe we're the world's largest exporter of sulphur.

DR. W.R. TROST

Now, depending on what the future may hold -- and your graph indicates that the production, as well as the consumption, of sulphur is apt to increase quite substantially -- what are your prognostications as to how long you may be stockpiling sulphur?

MR. D. SWANTON

Forever. Based on Figure 1-12, we've shown that the production of sulphur is going to increase based on our latest projections, and is increasing faster than the consumption of sulphur. Based on the data we have to date, we can't see any dramatic increase in the consumption rate for sulphur, and sulphur is a product which is sold on a world scale, and in relation to supply and demand, and unless we do something to change these projections, we are going to be continuing to sell sulphur at a distress price.

DR. W.R. TROST

Well you weren't able to answer the question earlier on as to how long you would be able to continue to produce sulphur from your reserves, but there would be a finite time, would there not?

MR. D. SWANTON

That's true. I don't have any indication myself as to how long that time would be.

MR. J.E. BAUGH

Mr. Chairman, the second chapter of our submission was the work of Dr. Katz, and he has now just come forward.

DR. SMITH

Before I ask Dr. Katz a question, I wonder if I could ask you, Mr. Baugh, to go back just for a moment to the figure we had just finished -- the tapering off of reserves by 1980, where they apparently taper off at something around 300 million tons of the known reserves of sulphur in the ground. If that's a realistic asymptote that shows that there won't be a dramatic increase in Alberta's sulphur reserves, it comes at about 1980. Would you anticipate a larger number of sulphur recovery plants going on stream after 1980? Do you think the possibility exists that there will be substantially more plants going on stream, assuming that reserve picture levels off and is a true....

MR. J.E. BAUGH

Firt you must consider the Athabasca tar sands in this picture. And just off-hand I'm sure that the Conservation Board did not include tar sands sulphur in this chart. They were talking about sulphur recovered from gas operations.

DR. S.B. SMITH

Yes, so that would go up if the tar sands were included?

MR. J.E. BAUGH

Yes, and I think that's the shape of the production curve which showed it going on. And we think probably the Conservation Board projected tar sands production in that second chart. From this chart we're producing about five million long tons a year now. We have produced about thirty million long tons, so that menas we have to hundred million long tons to be produced. The rate I think will increase some over the five million le level; we think it will go to six or thereabouts. But it's forty years at that rate, and I believe that this means there will be additional plants built, because we don't design these plants to have an economic life of forty years. So this graph imples there must be additional sulphur production plants in the period of the graph.

DR. S.B. SMITH

It would be something less than forty years then -- the life expectancy of these reserves: of our use of them, of gas.....

MR. J.E. BAUGH

We could say it another way, that the sulphur production rates will not increase for forty years. During that period quite clearly there's going to be a turnover, and the producing rates from natural gas sources will decline. I don't think there's any doubt about that. Our projection of production rates in total going up to ten million tons a year including tar sands implies we were thinking that in the next very few years there would be a turnover on that chart. We tried to figure out, behind the screen here, whether we had any statistics that would add to this story, we believe that for this decade we can expect production of sulphur to increase. In the 1980's we would expect a turnover in the rates.

DR. S.B. SMITH

I'd like to ask Dr. Katz a question now concerned with some of his researches going back twenty-five years or more onthe fate of SO_2 in the atmosphere specifically. Some of the data that are referred to in Global Effects of Environmental Pollution, prompts these questions. From your earlier work you suggest very strongly that air scavenging by water of SO_2 is very effective in preventing the rise of concentration of SO_2 in the atmosphere. In other words, it continues to pull it out?

DR. M. KATZ

Yes. Contrary to the fate of carbon dioxide in the atmosphere, which keeps on increasing year by year at a present rate of about seven-tenths of a part per million per year and may have undesirable global effects sometime in the future, the level of sulphur dioxide in the atmosphere has seemed to remain relatively constant at a very low level. This is because so far the industrial and other activities of man have not substantially increase the amount of sulphur dioxide released to the atmosphere to such an extent as to influence the global cycle to a steady build-up in concentration. One of the reasons for that is: if you looked at the consumption of fuels you find that on the domestic scene there's been a tremendous change in the type of fuels used. For instance, coal in western countries, especially in North America, is little used to provide heating for domestic purposes. We have a coat fed power plant, but over the last ten years or so the annual consumption of coal has remained at a steady rate, whereas there have been very great increases in the utilization of natural gas, which is clean fuel from the standpoint of sulphur content -- practically no sulphur in it -- and fuel oil. So the increased consumption of natural gas and fuel oil and only the steady consumption of coal mainly for production of electric power go along with the fact that there's been increasing control on smelters invoving the recovery of sulphur as sulphuric acid, or fertilizer or elemental sulphur. This has had a sort of stabilizing effect. I wouldn't guarantee that ten or twenty years from now we might not find sulphur dioxide levels starting to rise on a global scale, but so far they have remained remakably steady and in my report I've given three models of the global cycle. They don't all agree, although substantially they're fairly similar, but they indicate that thus far about two-thirds of the sulphur cycle is due to the sulphur from the death and decay of vegetation, and one third from industrial and other activities of man.

DR. S.B SMITH

We're saying that SO_2 is staying relatively constant in the atmosphere. What about SO_4, a sulphate in the ocean? From man's activities, more than from....

DR. M. KATZ

This is involved in the global cycle, and because you have phytoplankton in the ocean which utilizes sulphur, and you have the growth of plant life on land, etc., there is no indication of any accumulation of sulphate in the oceans.

DR. S.B. SMITH

What about the concentration of surface soil sulphur in this province -- in a general sense?

DR. M. KATZ

The studies of your own scientists in Alberta have indicated that there are areas in Alberta where you have a deficiency of sulphur. Sulphur distributed either in the form of fertilizer or sulphur released to the air as sulphur dioxide -- and eventually it is oxidized to sulphate sulphuric acid as a sulphate, deposited by precipitation -- has a beneficial effect in general on the Alberta soils because it does supply necessary sulphur in those areas where the sulphur is deficient. The experience has been that in many areas of the province, after some of these gas-processing plants went into operation, there has been a benefit to agriculture in the increased yields in certain crop areas.

DR. S.B. SMITH

Could you conclude from the three answers you've given to the concentrations in the atmosphere, in the oceans and in soils that the assimilated capacity of the biological systems which are either scavenging or providing a biochemical sink for sulphur is still to be reached, that it's still below their recycling capacity? Is that a fair conclusion?

DR. M. KATZ

Yes, that's my conclusion. We recognize that there are limited areas in Canada and elsewhere where soils have been affected adversely by high concentrations of sulphur dioxide released mainly from base metal smelting plants.

DR. S.B. SMITH

Such as Trail and Sudbury.

DR. M. KATZ

That's right. In limited areas, but even in the Slave area for example, the effect on the soil was limited to the surface, from about four or six inches depth, and I understand that after the recovery plants, fertilizer plants went into operation, those soils have recovered.

MR. W.A. FLOOK

Dr. Katz, in your summary you treat the effects of sulphur dioxide on vegetation, animal life and human health, and in no case is there an indication that sulphur dioxide concentrations, even several times higher than the prescribed ambient air quality standards, contribute any harm. In the case of vegetation there have been recorded instances of sulphur dioxide stress to vegetation in Alberta, and yet most of the plants appear to be conforming to ambient air quality standards. Is this an anomaly in measurement, or in the control limits, or ....

DR. KATZ

No. We've got to remember that there are two effects on vegetation from sulphur dioxide. There is the acute effect which can be due to damage caused by a short exposure to high concentrations, and there is the chronic effect which may be caused by long continued exposure to low concentrations. However, in the literature, both in our own studies and studies carried out elsewhere in other parts of the world, it's been shown that there is in fact a threshold value for sulphur dioxide in regards to susceptibility and injury to plants. For continuous levels, this is of the order of about one-tenth of a part per million; so a standard which

indicates that you shouldn't have any more than about one-tenth of a part per million for 24 hours is a good scientific standard. On the other hand, you couldn't have plants endure three-tenths of a part per million continuously over 24 hours. They would be injured. With three-tenths as I indicated in our own experiments, four hours per day is about the limit. When the state of California adopted its standards, it considered my own work and that of many others and came to the conclusion that for any one given episode, three-tenths for eight hours in daylight was a limit. And they didn't call this a threshold limit; they called it an adverse level because around there, and if you go any higher, you could get injuries, even at three-tenths. So I fully support the Mr. Baugh's statement. I believe that the Alberta standards are excellent and for sulphur dioxide have been based largely on effects on vegetation.
Now, on health, you'll notice in the standards of the Environmental Protection Agency in the United States they have, from a standpoint of public welfare which includes health as well, set their limit at half a part per million for three hours. Recognizing that this is a much higher level, I myself would hesitate to advise you to set the sulphur dioxide level at half a part per million for three hours for plant life, because I think that's too high.

MR. W.A. FLOOK

I suppose the same type of reasoning applies to effects on animal life as well?

DR. M. KATZ

Yes

MR. W.A. FLOOK

There's an interesting secondary effect that came to our notice recently.

It involves the disease known as nutritional muscular dystrophy, or White Muscle Disease, which is responsive to selenium treatment, and by implication is caused by selenium deficiency. The information that was presented to us indicated that sulphur is in competition with selenium as a plant food and would be selectively absorbed by the plant and selectively ingested by the animal later. This would indeed ultimately be a secondary effect on animals that is not taken into account in your effects of sulphur dioxide on animals.

DR. M. KATZ

Yes. This is an exceptional event. It's true that sulphur can replace selenium in biological reactions. I think, though, that the remedy is relatively simple in this case. If when the animals are given a dip in a solution for treating against let's say parasites, you add a little selenium to that dip, you can avoid this type of injury.

MR. W.A. FLOOK

In the case of effects on humans, Dr. Katz, you indicated that in none of the catastrophic pollution incidents was sulphur dioxide an important factor.

DR. M. KATZ

Well, I'd like to explain that a little further. In these urban situations we're not dealing with sulphur dioxide-flushed, relatively clean air, the way we are with, let's say, gas flares or smelters situated in rural areas. In the city, because there are hundreds of pollutants and there are at least a dozen major contaminants, it so happened that during these episodes in earlier years, the only thing that was measured was sulphur dioxide plus smoke concentrations in this suspended particulate matter. It's an easy thing for anybody to try and relate the increased incidence of deaths or sickness to what they measure, but unfortunately, they made the wrong conclusions. This doesn't mean to say that sulphur dioxide plus dirty air has the same effect as sulphur dioxide plus clean air. It hasn't. When you introduce particulate matter in appreciable concentrations added to sulphur dioxide, if you have the right kind of dust, you can get a synergistic effect so that the added effect of both these constituents is far greater than the effect of sulphur dioxide alone. And then if you add to it oxides of nitrogen and carbon monoxide which were undoubtedly present in the hydrocarbons, and polynuclear aromatic hydrocarbons, etc., then you're dealing with an extremely complex, sick situation. And that's why you will find that just the association of sulphur dioxide with these episodes is a great over-simplification of the effect, because you don't get those effects at all if you use either human or animal subjects and treat them with sulphur dioxide or with sulphur dioxide and minimum amounts of particulate matter.

DR. W.R. TROST

Dr. Katz, it was very interesting to have your presentation of the sulphur dioxide life cycle and the way it's analogous to the carbon dioxide life cycle, but some of the phases it goes through have more kick to them, I take it. Is that sort of a rough way of putting it?

DR. M. KATZ

Yes.

DR. W.R. TROST

Now, we've had submissions in some of our other hearings about human health, and the implication that these human health problems might have been associated with some aspect of the emanations from the plant. One submission more specifically suggested that a human complaint like emphysema could be associated with sulphur dioxide, perhaps through the synergistic associations that you've described. Can you comment on that?

DR. M. KATZ

Sulphur dioxide in itself, or relatively clean air cannot be associated with emphysema or with any of these respiratory symptoms; but if you take an urban atmosphere where you have comparatively higher levels of sulphur dioxide and carbon monoxide and oxides with nitorgen and reactive hydrocarbons, and suspeneded partiuclate matter, etc., then this type of environment is entirely different and is very much more hazardous than a comparatively free enviornment with just sulphur dioxide in it.

DR. W.R. TROST

Would you describe the emission that comes from an incinerator stack as a complex mixture of the sort that you've just described?

DR. M. KATZ

No. The incinerator stack emission's main component is sulphur dioxide. It's true that there may be a small amount of oxides of nitrogen with it. And very little if one has operated properly with the temperature of the stack emission of about 1000^{o} -- they should be practically invisible. There should be no smoke there. And the actual measurements that have been made -- and I've seen thousands of these measurements, both in the Pincher Creek area and elsewhere -- indicate very low levels of dust fall, or particulate matter and of sulphation rights. And also of sulphur dioxide levels. So therefore this is not comparable at all to a city environment.

DR. W.R. TROST

My memory suggests to me that you were involved in, and know something in a first-hand way about the situation in the Pincher Creek area from several years ago. Is that right?

DR. M. KATZ

Yes.

DR. W.R. TROST

Now, what about the emanations from the flare stacks, from which I think a somewhat different mix may be obtained than from an incinerator stack?

DR. M. KATZ

I agree that with flare stacks combustion can be much less efficient and, depending on the load on a flame, you may get incomplete combustion. So I think flare stacks are not as good a way of dispersing the combustion products as an incinerator in a properly designed stack.

DR. W.R. TROST

In an incinerator stack, I'm sure that the figure will vary, but the concentration of sulphur dioxide is probably quite high. Do you know offhand a figure you might give us as just a guide?

DR. M. KATZ

I don't think that the concentration in a stack has very much to do with the concentration at ground level, because the diffusion and dispersion that take place represent a dilution factor of from several thousand to ten thousand or more, so what difference does it make if you have one percent SO_2 if you're burning in the incinerator or, two percent? The difference is negligible, and the main effect of dispersion and diffusion is contained in the termperature of the gas, its velocity, the plume lines, and then the diffusion and dispersion downwind from the effective height of the source.

DR. W.R. TROST

I would like some rough indication from you as to what the parts per million SO_2 in the stack emission might be -- ten parts per million?

DR. M. KATZ

This depends on the efficiency of the gas-processing plant. It can vary from say one percent, ten thousand parts per million, or more depending on the efficiency of the processor.

DR. W.R. TROST

Now, this point is made in the submission at another place; it has to do with the mixing problem that you just described -- the dilution that takes place between the stack top and the ground level. In cases where there is good mixing, the kinds of dilutions that are needed are in practice obtained, but the brief suggests that in cases where that kind of mixing doesn't prevail -- when there are irregularities in topography, or when there are steady winds blowing in one direction, or when there are problems that prevent such a mixing, do you feel that conditions could so conspire as to produce ground level concentrations of sulphur dioxide from a relatively rich feed that might over many years produce effects on human health?

DR. M. KATZ

No, I don't think so. The thousands of measurements made everywhere throughout the province indicate that you have no situation anywhere that results in concentrations high enough to be hazardous to health. In the stack design the government regulations are sufficiently severe so that you might say the stacks are over-designed to take care of adverse situations such as those you mention.

MR. W. GUSELLA

I expect to be on next after these gentlemen, but now they have given some information which is quite contradictory to what I, as a practical farmer, have experienced. I farm at Carstairs and we have a section of land, half a section of which is two and a half miles south of the Carstairs gas plant of Home Oil Gas Plant, and half a section of which is about a mile east of that Home Gas Oil Plant. When they first started, Mr. Katz intimated that sulphur dioxide could not in any concentration harm human life. I was at one time seeding on this land east of the gas plant, which is just approximately one mile away, and if atmospheric conditions -- that includes wind velocity, moisture content, the atmospheric pressure -- if they are just right I have seen that smoke wave, air wave, air stream from that stack come down and hit me right within the mile. And at one time, while seeding, there was a southwest wind, a west wind mostly, and it hit me right on the seeding line and I could not get any fresh air. I have had experience in mine rescue work and I knew what was happening. I shut down the tractor and started to run at right angles; I was stifling -- this was a hot, acrid gas and I was short of air. I was just on the verge of blacking out when I crashed into the fresh air. And this happens quite often. Then, of course, we had other troubles with Home Oil, and I mentioned this to the Superintendent. Well, he says, we're in the process of changing the stack height, which will eliminate this trouble. Now it eliminated to a degree, but again, when conditions are right I have seen that gray, greenish smoke come right from the top, right down and hit the farm within a mile, a mile and a half of the plant. We have quite a windbrieak, quite an extensive windbreak, about thirty years old; the pine trees are about twenty-five, thirty feet tall. We have a variety of trees, and whenever the north wind is just right it will hit these trees, and we have seen what we called a 'gas burn'. This is just where the wind hits it, not where it's sheltered, but the outside exposed needles of these conifer trees will burn. This happened two years ago and a year and a half ago, and I reported the matter to the weed inspector in the county of Mountain View and he assured me he would be out there, but he never came out. Our neighbor to the south of us, a mile and a half, suffered the same kind of damage. He also reported it to the weed inspector with the same result as I had. Then again the gas concentration, if the wind was just right from the north, hit the south farm with this sulphur dioxide; and it seems to settle within the windbreak. We saw where my son's house, which is located in the same yard, within a matter of two to three days changed from a white to a mottled, blotchy gray, grayish-white, grayish-black, and the paint job is ruined. I reported this to Home Oil and they imeediately came out. The Superintendent happened to be away on a holiday, but the man just below him come out. They brought out a paint expert from Calgary. They sent samples to Edmonton, and then the Supertendent came out and he told me privately -- he wouldn't do it when there were others around -- but he said it is our fault -- there is sulphur in the paint. The analysis came back with sulphur in absorption in the paint, but he says, because you are the first one to complain we're going to contest this. Well, a paint job -- I'm not that financially well fixed. I backed down. I didn't contest it. I'll give you a more detailed explanation of a few other things when I come on.

DR. AZIZ

I am at the University of Calgary. I would like to state that we have been told this afternoon and this morning that it is not important how much sulphur you have at the ground level. I submit to you that it is not possible to accurately predict,with present technology, exactly how much sulphur concentration we would have at the ground level. And I also feel that there can be meterological conditions under which you would get plume to come and hit you at the ground level, as the gentleman just pointed out. And I think these things should be taken into consideration in designing plants and plant stacks, and I think this is perhaps part of the reason why a total emission standard has to be included in addition to a maximum ground level standard.

MR. D. ROLHEISER

I represent Alberta Business Locaters. Do you have a study of the noise ratings around the plant within one mile -- say, Jumping Pound or the other plant site?

MR. J.E. BAUGH

I don't have that information here; it's possible to get this information from those companies.

MR. D. ROLHEISER

I would also like to know when the oil companies are going to start paying for, pr purchasing, or recognizing, devaluation of property within a one-mile radius of the plant, and concerning pipelines.

MR. J.E. BAUGH

The question the gentleman has raised here is a little bit beyond the scope of my presentation, Mr. Chairman. I'm not here to speak on behalf of my own company. Being an association representative, I'd rather decline that question.

MR. D. ROLHEISER

When are the pipeline people are going or have to have, better security on their pipelines on major water thoroughfares like the Bow River, etc?

MR. J.E. BAUGH

Better security against what, sir?

MR. D. ROLHEISER

Breakage, sabotage, anything you.....

MR. J.E. BAUGH

I'm not aware of any incident where there has been a pipeline broken over the Bow River. I know several pipelines across the Bow River......

MR. D. ROLHEISER

Have you heard of any pipelines that have broken?

MR. J.E. BAUGH

Yes. Pipelines occasionally break.

MR. D. ROLHEISER

It's feasible then? Thank you.

MR. J.E. BAUGH

The only security measures taken are in the design, and industry people do an excellent job in this as indicated by the number of times we cross rivers and the very few times that any oil or gas or any other foreign material has ever gotten into a river. In fact, I don't know of a case in the province. Perhaps you could advise me of one where we have had a pipeline failure with subsequent spill into the river.

MR. W. CHALMERS

I think in a gas plant generally the greatest noise source is from the sulphur plant blowers. Quite a few years ago, I think it was 1964 or 1965, we had what we thought was an intolerable noise level situation in the sulphur plants. It was running at 114 decibels and an extremely nasty frequency. It was a frequency that got you down quite deep. We corrected this situation by fitting silencers on the intakes of these particular two blowers. When we expanded our plant facilities in 1966 and 1967, we built what was to be the largest sulphur plant in the world; we actually doubled the size of any sulphur plant from 500 tons to nearly 1100 tons per day. This involved a very large blower, 2800 horse poer steam turbine. I think the capacity blower is 76,000 cfm. We ordered a silencer for our blower in the initial stages. We were successful in reducing theat whole noise level in the sulphur plant to around 90 decibels. Ninely decibels was still quite loud in certain respects. I don't think it's as loud as a DC-8 or any of the jets we're subjected to, but we did get rid of the particularly nasty frequency that we had at that time. I think the only other source of noise in the earlier years from gas plants or field operations came from the blowing of wells after stimulation. These did scream at a fairly high pitch. And with the new environmental regulations that came out two years ago prohibiting flaring, and the improved operations from most of the plants where there is very limited flaring now, I think the noise levels (from gas operations) generally over the whole province are reduced or practically non-existent. They are in our case anyway.

DR. W.R. TROST

Mr. Baugh, are there any questions that you might like to address to Dr. Katz in view of these discussions?

MR. J.E. BAUGH

We thought that Dr. Katz's special expertise might be of help to the Authority; this arose from the questioning or the discussion immediately before adjournment. One of the gentlemen spoke about his experience in exposure to sulphur dioxide fumes from a stack in Alberta and we didn't really get direct evidence. I wonder if Dr. Katz would give us his thoughts and his experience on the threshold concentration of SO_2 as it applies to a human being.

DR. M. KATZ

The concentration of sulphur dioxide can be tasted. You can taste it on many occasions before you smell it. For an experienced person it is of the order of 0.5 part per million, perhaps a little less. Now you can begin to smell it, depending on the individual who is doing the smelling and his sensitivity to it, at about 1 - 3 ppm; what this means, of course, is that occasionally if you get a looping plume -- and this can happen -- in other words, under certain meteorological conditions the plume will loop to ground level at some point downwind from a stack and then it will bounce up reflected from the ground, rise and loop again. Now this condition, the looping plume, can occur during periods of high atmospheric turbulence, so that momentarily you may get higher concentrations at ground level than predicted by theory, but the duration of these concentrations is very short. Under those conditions a person in the path of a plume may detect the concentration by odor even though it is only present for, say, less than a minute, a matter of seconds or a matter of a few minutes. The odor of sulphur dioxide and its effects are quite different from hydrogen sulphide. Hydrogen sulphide in these concentrations can cause lull factory fatigue. In other words, several ppm of hydrogen sulphide can lull a person after a while into thinking that it is no longer present, while as a matter of fact it is there. In the case of sulphur dioxide the irritations persist as long as the gas is present so that you have no difficulty in knowing you are in the presence of sulphur dioxide; the natural reaction of course is to find the concentration and try to get out of it. Have I answered your question?

MR. J.E. BAUGH

I am concerning myself particularly with the gentleman that was on his tractor and encountered this sudden occurrence of sulphur dioxide from the stack. I wondered what in your views the concentration might be, to result in the reaction that he had.

DR. M. KATZ

I think that he was subjected to a looping plume condition. The concentration is a matter of guess work. I wouldn't guess at the concentration, except that I would think that it was over 1 ppm for a short period if he detected it and thought that it was unpleasant to him. I noticed that there was a gentleman here that spoke on the question of emission standards. Although it is true that some control agencies impose emission standards as well as ambient air quality standards, the emission standards are not really an effective way of controlling air pollution. I will give you an example. You may find that you have several plants or concentrations of industrial plants in an area; although each of them is conforming to the emission standard, the combined effect is that your ambient air quality standard is greatly exceeded. Emission standards are very convenient from the standpoint of certain industries because they may be able to meet the emission standard with far less trouble and far less operational control equipment than if they were required to meet an ambient air quality standard. As a matter of fact, we don't care what the concentration is in a stack because we don't breathe the atmosphere of a stack; but we do breathe the air at ground level and this is where the important criteria should be and where the standard should be directed.

DR. S.B. SMITH

Dr. Katz, in Alberta as well as elsewhere on the Canadian prairies, I am sure that you are aware that with the heavy sudden rainfalls and then subsequent high heating, we get extreme turbulences. Anyone who has flown anywhere beneath 1000 feet here in the summer can say this. How much can a looping plume convey to the ground? Let's put it another way. How little dissipation could occur in a looping plume? How definitive or how narrow can that plume be? Can it come looping over and down in a condition of high turbulence virtually undiluted from the stack mouth?

DR. M. KATZ

No. Actually a looping plume occurs during periods of high atmospheric instability, high turbulence. Under those conditions you get a maximum concentration at ground level; it will occur only for a very short period of time. I think that the worst conditions are when you have low wind speed, calm weather, an inversion condition and a definite ceiling height -- in other words, where the stack emission cannot penetrate the phase of the inversion. If you have a low ceiling height or a low mixing height, then the only confusion that can occur is between ground level and that mixing height; under those conditions of course you get the highest concentration of a fairly long duration. Those are the conditions that in general can lead to plant damage due to excessive concentration. In my experience in the Alberta area I haven't encountered any evidence of crop damage.

DR. S.B. SMITH

What is the maximum concentration that you are aware of where a stack is normally operating efficiently and the plume may loop or there may be some other adverse condition? What do you recall in the way of upper concentrations of SO_2, H_2S or other sulphur compounds?

DR. M. KATZ

I can refer to the experience in the Sudbury area, where there is a relatively large amount of sulphur dioxide discharged to the atmosphere. As you heard in the presentation by Mr. Baugh, out of an analysis of thousands of fumigations only a small number were potentially damaging -- in other words, had the potential to cause damage -- but all of them did cause damage. Nevertheless, there are times there during the growing season when you can get damage to crop plants and trees, and these damaging fumigations are accompanied by concentrations that run well over one part per million. They run up to between one part and three parts per million.

DR. S.B. SMITH

At those concentrations, would they then cause respiratory difficulties for a person in that area?

DR. M. KATZ

There is no evidence that anybody in the Sudbury district has complained about health conditions.

DR. S.B. SMITH

That was not my question. I wonder if a person exposed to those concentrations, well over a part per million, would have respiratory difficulties?

DR. M. KATZ

He might of course find it unpleasant. Others would not. It would depend entirely as to whether he was suffering from asthma or from some kind of respiratory condition which made him extremely sensitive to any change in atmospheric conditions.

DR. W.A. FLOOK

I would like to pursue this plume concentration thing just a little bit more. In addition to what you described as looping plume there is another classical plume conformation. This is characterized by a flat upper layer and a slope downwards to the ground, and I believe it is called ventilating.

DR. M. KATZ

There is a coning plume, which is really the classical type of plume upon which most of the diffusion equations are based. There is also the fanning type of plume, which denotes an inversion condition. Actually, during most inversions that fanning plume will not meet ground level except during the breakup of the inversion, and then of course the ground is fumigated.

DR. W.A. FLOOK

The point that I was trying to make is that there is the classical type of plume that can occur where, in the absence of turbulence that could dissipate the plume, the material from a stack can in fact come to ground relatively undispersed. In addition to this, characteristically a plume emerges in puffs. The concentration in the plume varies. If the concentration in the stack averages, say, 10,000 ppm as you quoted earlier, then it is conceivable that the concentration in the plume might vary from, say, 20,000 to 5,000.

DR. M. KATZ

Not in the plume, because if you have 10,000 ppm in the stack, as soon as that plume leaves the stack it begins to be dispersed by eddies. This eddy is very much more efficient than ordinary molecular diffusion, so that downwind -- even before the plume reaches ground level -- it has decreased greatly in concentration. During the period of a fumigation with a fanning plume under inversion conditions, first of all that plume has spread out a considerable distance above ground level. If there is no change in atmospheric conditions (for example, consider a typical night-time inversion; the plume from a stack can be seen fanning out for many miles and lots of people see this) at that time there is no ground concentration at all because that plume is up aloft. In the early morning when the sun starts to warm the surface of the earth, you begin to get the breakup of the inversion. An inversion is simply that the air that goes to the ground is a lower temperature near rock; as soon as the air near ground level starts to warm up you begin to break up the inversion and that is when you get a fumigation underneath this fan-shaped plume, but since the plume has spread out for many miles, the ground concentration is greatly diluted. In the Sudbury district the emissions from three smelters are relatively enormous compared to your gas plants here. Maximum concentration levels seldom (about once during a whole six months) exceed about 2 ppm. Something higher might get up to about 3 ppm. The records of these fumigations are variable in reports going back 25 years. There are 10 or 12 sulphur dioxide continuous monitoring stations operating in that area; all those data are available and they indicate that over the years there has been damage to forests and, under certain conditions, damage to crop plants, but this is really the most fumigated area in Canada. There is no other area in Canada comparable to it, and what you have in Alberta doesn't begin to compare with this area at all.

MR. W.A. FLOOK

It may be that the record failed to indicate concentrations in excess of 2 or 3 ppm at ground level. It seems that if a plume emerges from the top of the stack and descends to earth within a mile relatively unchanged, and emerges at concentrations of 10,000 ppm, when you bear in mind the visual appearance of a plume (for instance, a water vapor plume in winter) you can see it traveling for relatively long distances with its optical density apparently very little changed. You can see that a 3000 times dilution is really quite a considerable amount to achieve because that is what it would take to drop the concentration.

DR. M. KATZ

You can't compare water vapor with the plume from a stack at about 1000 degrees. A water vapor plume is what we call a plume and by the nature of the water vapor it condenses; but the sulphur dioxide does not condense and it remains as a gas, whereas the water vapor is really particulate matter and you might compare it to a great cloud of dust which is being poured out of a stack. It depends on the size of the drops or the size of the particles whether it will fall in the vicinity of the plant. This is an entirely different situation and you can't compare a water vapor plume with a gas plume at all.

MR. W.A. FLOOK

This is possible, but in addition to that, when a very hot plume emerges into the comparatively cold air, would there not be a tendency for the plume to shrink and concentrate itself before it began to disappear?

DR. M. KATZ

The only thing that will reduce the rise of that plume is an extremely high wind. This is quite evident when you start to use the plume rise formula. Now, a plume issuing from a stack at 1000^{0} F will require about a 50 mph wind to nullify that plume line. In a 50 mph wind you don't worry about ground concentration at all because the dispersal is tremendous.

MR. W.A. FLOOK

There is one other question that I wanted to ask. On page 212, and I will quote the paragraph, "It is apparent that with regard to natural gas processing and sulphur recovery operations in Alberta and in other industrial processes involving emission of sulphur oxides, under the present government control regulations no health hazard exists from the relatively low ground concentrations that may be found in the vicinity of such operations." Quite a few people have assured us that health hazards do exist, and in fact they have been victims of such health hazards. In coming to this conclusion were people living in the vicinity of these plants interviewed as to their experience, or was that conclusion based on theoretical consideration?

DR. M. KATZ

This is based on the findings of the numerous monitoring stations, the sulphation candles and the available scientific knowledge. I am not going to argue with the personal opinions of people who say that their health is in some way affected. All I can say is that if you look around the province you will see thousands of people living and working and conducting farming operations in the areas of your gas processing plants and I know of no scientific evidence that can relate the ground concentration monitored with health effects.

DR. W.R. TROST

You indicated that certain individuals might be more sensitive perhaps because of asthmatic or other conditions. I would like you to elaborate on that and describe to us whether classes of animals or age groups within classes of animals may also be more susceptible to these two exposures, particularly to sulphur dioxide. I have in mind the distinctions that may be found between ungulates like cows or pigs, that have been described to us as being perhaps particularly sensitive, and the human species. Would you comment on whether or not children might have a sensitivity greater than adults, or less.

DR. M. KATZ

Going back to the industrial hygiene standards, why was it set at 5 ppm for eight hours per day, five days per week for healthy adult workers? It is because experience and experimental work indicated that healthy adults could tolerate that kind of concentration level. I would not suggest that you could put a child into that kind of atmosphere. Certainly not. Or an elderly person or any person that suffers from some respiratory infection or some heart condition and so on. Certainly not. So the actual standard has been reduced by factors somewhere between 10 and 100, because your standard says you should not have more than 0.3 part per million for one hour. Compare that with 40 hours in a week of 5 ppm. In other words there has been a tremendous safety factor incorporated into the ambient air quality standards, and this has been done in order to take care of situations where you have elderly people and children present, and so on.

DR. W.R. TROST

There may well be a significant variation in the susceptibility of individuals or age groups?

DR. M. KATZ

There is a variation of susceptibility.

DR. W.R. TROST

I would like to return to the looping plume but in a different context. It is so familiar to us, living close to the mountains, that inversions can occur at varying heights and sometimes quite close to the ground. We can see that plumes going up to those inversion layers -- if they happen to be above the stacks and they may hit the inversion layer just above the stack -- will go up straight and then they go horizontal. There may be, in some circumstances, confining winds that keep that horizontal plume traveling along the bottom of the inversion layer, moving in what is evidently a straight direction without too much confusion. Have you, or to your knowledge has anyone else ever calculated the minimum pollution factor that can occur under a combination of unfavorable circumstances?

DR. M. KATZ

Yes. Years ago I used to do a lot of atmospheric sampling. I used an airplane and I measured plumes in the Sudbury district, and flew with them and across them.

DR. W.R. TROST

Have you done them here?

DR. M. KATZ

No, I haven't done them in Alberta. I have done them elsewhere.

DR. W.R. TROST

Has Sudbury got chinooks?

DR. M. KATZ

No, Sudbury has not got chinooks, but they do have inversions.

DR. W.R. TROST

But it is the combination of the two things, is it not -- both the inversion at a variable and sometimes a low layer as well as confining winds sometimes formed by the mountain system that are prevailing in one direction?

DR. M. KATZ

You have a great advantage here in your incinerators, in that the temperatures at which the gases are discharged are so high, because the average smelter stack operates between 350° and 450° degrees up and no higher. Sometimes in certain areas they will even add a stack heater to raise the temperature another 25° to 50°. This, you will appreciate, is a very expensive proposition and is only resorted to as a last effort to prevent damage to vegetation, and it is not always successful. I don't think that in Alberta, and you would readily see if there was a failure of dispersal by the given stacks, you would see widespread damage to either cereal crops, alfalfa or forest species.

DR. W.R. TROST

We have the evidence by testimony that individuals have experienced it, so it is not the matter so much as to whether or not it has been noticed -- it is more a mathematical question. Has a minimum dilution factor been calculated in theoretical ground?

DR. M. KATZ

This is very difficult to do. Of course you can do it on the basis of certain levels. Certainly you can do it. You can calculate concentration in the plume as well as at ground level, certainly.

DR. W.R. TROST

Has it been done?

DR. M. KATZ

Yes, I am sure it has been done.

DR. W.R. TROST

Could you give us a reference?

DR. M. KATZ

I am sure that Joe Lukacs has done this.

DR. W.R. TROST

He's not as sure as you are.

DR. M. KATZ

Your government people have done this.

DR. W.R. TROST

I am not so sure. Do you know from your own knowledge and if you have it can you share it with us?

DR. M. KATZ

This has been done and it certainly can be done. There is no difficulty about it.

DR. W.R. TROST

I want to know if it has been done.

DR. M. KATZ

I am sure it has been done in Alberta.

DR. W.R. TROST

Then the answer? If it has been done, what is the answer?

DR. M. KATZ

I think that this was also done by Dr. Schmidt of the University of Toronto in a case involving the Hermitage area near Edmonton, where it was proposed to build up the lake and land there now right up to the boundaries of the industrial district. At that time it was preventative evidence showing what the concentrations could be under various conditions.

DR. W.R. TROST

You haven't such a minimum dilution factor for your submission today?

DR. M. KATZ

Not for today. I didn't think it was necessary.

DR. W.R. TROST

I just want to follow up the point brought up earlier having to do with secondary effects, in which sulphur might displace selenium and consequently and directly become associated with animals suffering from a selenium deficiency. Do you want to elaborate on that point any further?

DR. M. KATZ

I don't think so, because I think this is not a general problem. This is some specialized condition and there is a remedy for it, but I don't anticipate that it is a problem of general interest or application.

DR. W.R. TROST

In respect of the treatment for selenium deficiency in livestock animals you mentioned a kind of a cure, which was selenium added to a dip in which animals might be exposed to. Have you other ways in which....

DR. M. KATZ

There are probably many other ways which I think a competent veterinary doctor would suggest.

DR. W.R. TROST

Can it be used as a feed additive?

DR. M. KATZ

This is risky because you can also exceed the level of selenium and then induce selenium toxicity.

DR. W.R. TROST

You don't know which one to choose then? Are animals that normally feed on grasses and so on to be treated in the same way as animals who are more omnivorous?

DR. M. KATZ

I have never encountered a case of any effects on animals feeding on forage or other crops that have been exposed to non-injurious concentrations of sulphur dioxide. Completely harmless. In other words, these crops may have somewhat higher levels of sulphur in the leaves than crops that have never been exposed to sulphur dioxide. but that sulphur -- whether it is in the form of organic sulphur or sulphate -- is not toxic to animals.

DR. W.R. TROST

Unless it indirectly leads to the deficiency of selenium?

DR. M. KATZ

This is a specialized case, and it is very unusual to induce selenium deficiency; in fact it is more usual to have selenium toxicity.

DR. S.B. SMITH

Are you aware of the research at the University of Guelph on the lake waters around the Sudbury area downwind of the area? It is true that pH values of less than 5 and approximately 4 have been found in some of those waters, and that no vertebrate life whatsoever exists in those waters? Is it true? At least I've seen published information on it.

DR. M. KATZ

Yes. There has been published information on lowering of the hydrogen ion concentration in the waters in some of the lakes.

DR. S.B. SMITH

Sudbury certainly isn't here, and the shield isn't Alberta. We recognize this and they are difficult to compare, but you emphasized only a very few instances of high concentration of SO_2 at ground level in the Sudbury area, did you not?

DR. M. KATZ

No. I didn't intend to create that impression. The levels of concentration in the Sudbury district are what I call relatively high. In other words, the levels are very much higher than what you would get anywhere in Alberta, or for that matter in other parts of Canada except for a few smelting districts where they have the same problem of a high emission of sulphur dioxide. and although there is some recovery of the sulphur dioxide as sulphuric acid, the economic condition and lack of markets prevent further recovery of sulphur dioxide.

DR. S.B. SMITH

Didn't you say that the ground level concentrations of 1 or 2 ppm measured through those monitored areas were very rare in the Sudbury area?

DR. M. KATZ

We cannot talk of concentration without introducing the exposure factor as well, because a concentration by itself is meaningless unless it is accompanied by a duration. What I said is that although there are large numbers of fumigations in the area that can rise up to over one ppm, the number of such fumigations that actually cause damage is relatively small. In other words, it requires so many hours at these higher concentrations in order to cause injury, and if the fumigation is short or if the level of high concentration is short no injury will occur.

DR. S.B. SMITH

Then you are saying that the devastation there has been caused by persistent low concentrations?

DR. M. KATZ

No, mainly by the higher concentrations. It has been shown that if you remove the high concentration level -- first the concentrations higher than 0.5 ppm -- then the area would be relatively safe from damage. In fact this is what happened in the Trail smelter district where as a result of the recovery of sulphur dioxide, which was raised over a period of years to about 90 percent, they still registered sulphur dioxide fumigations in the Columbia River valley. The concentrations were much lower than formerly and the high concentrations, say above 0.5 ppm, disappeared entirely. The result was that the growth of both trees and other vegetation was resumed and trees that had shown retardation in growth actually started to recover.

DR. W.R. TROST

Dr. Katz, do you want to add anything to your testimony before you leave?

DR. M. KATZ

I don't think so. I think we have covered a great many aspects. I want to reiterate again that I think that you have a very good environmental quality program in the province of Alberta, in many respects the best in the country and one of the best in the world. I hope you keep it up.

MR. J.E. BAUGH

When you were questioning our group prior to the dinner hour you had some lack of complete answers in the questioning regarding two of our charts dealing with sulphur production and sulphur reserves. We do have another witness that has had a couple of hours to get prepared, and we are prepared to resume on that if it would be of help to the Authority.

DR. W.R. TROST

I think that would be helpful to us, Mr. Baugh.

MR. J.E. BAUGH

May I introduce to you then Mr. Hans Maciej, who is the economist on the staff of the Association and Assistant to the Manager.

MR. H. MACIEJ

There seems to be a considerable amount of confusion about the first chart that we have on the screen now. I thought some of the erroneous, misleading portions had been covered in the errata, but apparently they were forgotten. Let me first point out that this curve and the top curve represent capacity, and the flattening out of the curve at the very top simply reflects a temporary discontinuation of new gas processing plants coming on stream. Once new plants come on stream of course, this curve will then continue to rise but at the moment we have a temporary flattening. As far as the other two curves are concerned, they simply represent the total gas production. Here we have the total production of sweet and sour gas and here at the bottom we have the export of sales gas to the United States. There should be a correction on this side, and that is that it is a trillion cubic feet per year and this would be 1.0 and 2.0. In other words, for 1971 we exported 0.9 trillion cubic feet of gas to the United States; the total production of raw gas that includes sweet and sour gas was about 2.1 trillion. I hope that this will clear up this chart to your satisfaction. The other two charts that I would like to deal with then are the one on reserves showing the Alberta sulphur reserves and in conjuntion with it the chart on projected Alberta sulphur production. We must keep in mind that this curve represents the cumulative amount of reserves found. Therefore if we transpose onto this one the production on an accumulative basis, you will find that we have a similarly shaped curve, although it will be rising steeper and eventually end up at the same point. At no time in the future can cumulative production exceed this end point. You will see that it is estimated that the ultimate reserves in Alberta by the year 1980 will be about 240 million tons. My understanding is that the estimate of the potential sulphur reserves from conventional resources in the province are estimated at 250 million tons. That excludes the sulphur reserves in the Athabasca tar sands or any of the oil sands or in reservoirs such as Panther River. In other words, we might call these the conventional sulphur reserves from sour gas. This curve simply reflects what we expect to add in the next few years to ultimately reach the figure of 250 million tons.

DR. W.R. TROST

Would you clarify for us whether this chart shows the sulphur that is unrecovered, or does it show both sulphur recovered and unrecovered.

MR. H. MACIEJ

It shows both recovered and unrecovered. Out of this total amount approximately 26 million tons have been produced so far; this is an accumulative reserve chart, so if you would pick, say, the total number about 1971, which is about 180 million long tons, the remaining reserves at the end of 1971 were about 180 million tons. The ultimate at that time was 206 million tons which would be the figure that....

DR. W.R. TROST

Yes, that is perfectly clear.

MR. H. MACIEJ

We cannot compare the two curves -- the one on any production was accumulative -- but we could show the similar. Going back to figure 11, where we show Alberta sulphur production up to 1982, this is sulphur production in Alberta on an annual basis and the production in 1971 was about 4.5 million tons. We expect this production to rise in the future. Our reserves are represented by about a 40-year life at the moment, and with the increasing production we will expect that the life index of our sulphur reserves will decline. You will see a flattening of the curve in the period 1975 - 1976 which reflects the flattening of the accumulative sulphur reserve chart that we just looked at. Then you see another sharp rise coming in and here we are looking at Athabasca sulphur production. As tar sands plants come onto production we will then again see a rise in sulphur production, while from the conventional sources we will see a levelling off of production, and eventually somewhere between 1980 and 1985 probably a decline from conventional resources.

DR. W.R. TROST

Now, if we can put that together from figure 1.1, does the plateau that exists at the 1970 - 1972 horizon arrive at something like 23 million? Is your projection now that that plateau will continue roughly at that level until it drops?

MR. H. MACIEJ

The sulphur production capacity?

DR. W.R. TROST

Yes.

MR. H. MACIEJ

No, that will in the future rise again. This is simply a temporary flattening dictated by the decision of the National Energy Board to disallow further exports to the United States.

DR. W.R. TROST

So it will rise somewhat again?

MR. H. MACIEJ

Yes, it will rise again.

DR. W.R. TROST

In your other curve you showed a calculation that had input from the tar sands, but that is not relevant to us right now.

MR. H. MACIEJ

No.

DR. W.R. TROST

Do you want to comment on what might be the life expectancy that these figures show? How long will you be producing sulphur with these plant capacities and these reserves?

MR. H. MACIEJ

I haven't calculated it out, but at the end from a typical reservoir you get a very long flat line at the end of the decline rate, and that is when that life stretches considerably. You will not get the quantities but you still will get sulphur production. You will have a considerable decline from the present or future rates but you will still maintain production simply because the reservoirs perform in such a way that at the tail end they have a long life at a low rate.

DR. W.R. TROST

I think that is a perfectly clear answer, unless you want to give some indication as to when the peaking time will occur when your rate of production will begin to fall.

MR. H. MACIEJ

As I indicated from conventional resources, I would think that the peaking will be somewhere between 85 and 90.

DR. W.R. TROST

Another question is in what way the economics of sulphur production and marketing might affect the rate of production and vice versa.

MR. H. MACIEJ

I think that we should make it absolutely clear that in the now foreseeable future, and maybe forever unless we are lucky enough to find some other use for sulphur, the industry doesn't want to produce sulphur. However, due to conservation and environmental control requirements, we are required to take the sulphur out of the gas. While perhaps in the past calculation of the economics of any plant project we looked at the income from sulphur as an enhancing proposition to the profitability of the project, I think that it is quite clear -- and everybody should be aware of it -- that economics in the future will be based on the zero value of sulphur. We are losing markets right and left simply because of environmental considerations in other parts of the world where the emission controls are being tightened and people have taken sulphur out of the gas effluent and are providing their own markets. We are losing markets right and left. We have now over 5 million tons in stockpile in Alberta and it is rising at well over 1.5 million tons per year. There are plants in the province which didn't even install a railroad spur because there was no market for it, so future economics will consider the value of sulphur at zero. This of course means that the cost of recovering that sulphur and of any environmental control regulations must be covered by the price of natural gas. And this is perhaps one of the most important reasons why exploration for natural gas in the sour gas prone area of the foothills has almost come to a standstill. Simply, at the low gas price, it is unprofitable to pursue those projects. The gas price must rise. If environmental controls force additional cost on sulphur recovery then we are looking at sulphur prices far in excess of 35 or 40 cents at the wellhead to make those projects viable. And the only alternative to that is, if the economics are not there we cannot produce the sulphur and we eventually will run out of resources.

DR. W.R. TROST

Some of the companies have told us that they were selling their sulphur as they produced it, and others, I think, have been stockpiling all the material they've produced. Have you overall statistics for the companies in the province as to what percentage they're stockpiling and what percentage they're selling?

MR. H. MACIEJ

Well, I would say everybody would like to sell as much as possible. The inventories are climbing at about 1.5 to 2 million tons a year. In other words we are only selling a little better than fifty percent of our production, and I would say that while we're all looking for markets, some of the plants which have no facilities for getting the sulphur out are making exchange arrangements such as we have under the Petrogas Processing, where unit trains take out sulphur that actually other people have sold. But, it is very, very difficult to find new markets today.

DR. W.R. TROST

Now in many cases, I believe, the gases from different fields are mixed so that very sour gas may be diluted a bit with sweeter gas; in that way both are processed and a market found for the combined product. I'm trying to ask a question that will indicate to us what constraints sour gas may be under in the market place as against sweet gas in a market situation that seems, in the future, to be one for a rising price for the final commercial product.

MR. H. MACIEJ

Are you driving at a two-price system for sour and sweet gas?

DR. W.R. TROST

I'm not. I'm sure that you people might try but....

MR. H. MACIEJ

I don't think we even want to look at it.

DR. W.R. TROST

Are you having any trouble marketing your gas from whatever source profitwise?

MR. H. MACIEJ

Yes, we are; there is gas marketed today which certainly is unprofitable, without any doubt. With the sulphur price dropped to the level that it has today, there is little doubt that at the moment there is gas being sold which is unprofitable and it's only in the hope for higher prices in the future that it will be recovered. I'm referring there to projects that had considered some sort of sulphur price in the profitability, certainly at higher levels than today; economists are also human beings and make errors. If we were smart and could always predict the future I don't think we would be working for our companies -- we would be owning them. And so it becomes very difficult; while some of the economists no doubt were very optimistic in years past about the sulphur price, they were misled by some of the predictions that were made, particularly by the fertilizer industry around the world. Their profitabilities were based undoubtedly on a higher price of sulphur than is prevailing today, and these projects are suffering. There is little doubt about it.

DR. W.R. TROST

There have been some indications made to us that, despite the fact that the picture is a bit confused by the stockpiling situation, wheat has been stockpiled in the past and it of course presented a problem then, but it's hard to find a wheat stockpile now so that you can place these things into context. Under present circumstances, that is to say under the market situation and the guidelines that have been obtained in the past, was not, in fact, sulphur produced profitably as a part of the overall operation?

MR. H. MACIEJ

I wouldn't say the sulphur itself was profitably produced. I would say the overall economics of the plant were all right. I would not say, if you were able to allocate the cost directly to the sulphur train, that the sulphur in all cases was profitable. Don't forget we only had a very, very few years of high prices -- the rest of the time the prices have been low, and while you have been asking how do companies look at inventories or stockpiling, I think one must keep in mind the time cost of money. For example, you have ten-dollar sulphur going and you decide that you anticipate a higher price because you anticipate a shortage, so you put it into a stockpile. You must appreciate that ten-dollar sulphur, seven years later at nine percent discount or compound, has to give you $16.80, and then you're just even, you haven't done any better. Now I would say nine percent is a very low rate. I think a yearly risk industry looking at fifteen percent would be more realistic. So I don't think companies look very favorably upon stockpiling.

MR. J.E. BAUGH

We are available now for questions on Chapter Three, or any other chapter that you wish to open.

DR. S.B. SMITH

I mentioned this to you off the record earlier and the question deals partly with legislation but partly also with the economics of sulphur sales. Initially -- say ten years ago -- before there were any great environmental concerns in the minds of the general public, was it the attractive price of sulphur, or legislation, or both, that dictated the relatively high recovery of sulphur that has been meant for instance by some other people giving evidence here?

MR. J.E. BAUGH

To my knowledge there have never been any recovery facilities installed simply to recover more sulphur. I think it's fair to say that at some point when sulphur prices were extremely high -- and by that I mean fifty dollars a ton -- at that point in history there were some projects that kicked off and were constricted, that were depending on sulphur revenues for a large part of their revenue as well as gas and other products. Those projects looked quite attractive at that time, but not simply because they were recovering ninety-eight percent or ninety-five percent instead of ninety-one. They were viable projects at the time. I am sure that those are probably the same projects that Mr. Maciej has just told you are unprofitable today.

MR. W.A. FLOOK

Mr. Baugh, in your chapter on legislation you indicate that in July of 1970 the relative functions of the Energy Resources Conservation Board and the then Department of Health were clarified, but you say this clarification was short lived because of minimum sulphur recovery efficiency guidelines. Would you like to elaborate a little bit on that? Why would the publication of minimum sulphur recovery efficiency guidelines by the board have caused further confusion?

MR. J.E. BAUGH

This has been mentioned by several of us to the Authority today -- that the imposition of emission controls on top of air quality standards creates the confusion. In our view the Energy Resources Conservation Board, which in 1970 was assigned the task of policing our operations, was thus put in the position of imposing a standard of its own, which seems to supersede in many ways the air quality standard which emanates from the Department of the Environment. This is the area of confusion.

MR. W.A. FLOOK

Wouldn't you say it's rather an added complication or an added complexity rather than a confusion? It's the word 'confusion' that I have difficulty with; it has two sets of standards. They are not incompatible; at any given time you may meet one and not the other. But in order to achieve complete protection from the environment it could be argued that both must be met consistently, and failure to meet either one could have an adverse effect on the environment. I don't see the aspect of 'confusion' so clearly as I see the aspect of 'complication'. Would you agree with that?

DR. W.R. TROST

Mr. Baugh, we want to give full attention to your major recommendation from the C.P.A. that ambient air quality, rather than either arbitrary efficiences or standard emission controls, be the basis for resource management in the industry.

MR. J.E. BAUGH

That's our position; we have tried to demonstrate that air quality in fact is what we are here for and what we are trying to protect, and we feel that the extensive evidence given by Dr. Katz demonstrated that the air quality standards are adequate to protect the environment. So we stand on that position.

DR. W.R. TROST

Well, we will certainly take it on. Perhaps we should continue with the matters that are relevant to it, but still subsidiary to it. I am interested in two things; first of all Chapter 3 describes a fairly long history of industry and government interaction in bringing about change and an improved resource management system, even though the chapter does describe the odd difficulty that in fact you did work through. Do you have confidence in this general way of operating, in which industry and government do talk through their problems and try to reach systems of resource management that are practical and sensible from their respective points of view?

MR. J.E. BAUGH

Yes, the Association advocates and supports this type of communication that we have here today. We are very pleased to have had the opportunity to put our case before you, and to bring our experts forth and have you question them. We think this is the way it should be done, the only way it can be done, to the public's best advantage.

DR. W.R. TROST

And your experience is that it works; that it's a practical way of doing it?

MR. J.E. BAUGH

It works, yes.

DR. W.R. TROST

Now in your last paragraph on that chapter you suggest that future control programs must be based on the results of the research by the academic, government and private sectors and should not represent an over-reaction to public pressure. Do you want to elaborate on that?

MR. J.E. BAUGH

I believe the sort of evidence that we have endeavoured to introduce today through Dr. Katz, other speakers whom you have heard and others still yet to be heard, about the experimental field observations of these exposures, these fumigations, is the sort of information that should be used, rather than just an arbitrary decision or undertaking by government to say we had better tighten up on these regulations. We had better make a more stringent atmosphere for these industries because we want to protect our futures and our children's futures. We in industry have exactly the same objective; we live in the province, we raise our families in the province, many of us live in sight of gas plants, we work in them every day, we have the same objectives, so our position simply is: standards should be set on the basis of research results, and those can be broadened to include field investigations of the many types we have heard about today.

DR. W.R. TROST

I know you are familiar with the research programs and the environmental effects of sulphur plants in the Whitecourt area, and the work that is being done in the Pincher Creek area. Do you feel that there is a place for that part of the public that is directly affected by these environmental effects, so that they might also have a place on the committee or the group that establishes the research program and also evaluates it, so that their experience as human beings exposed to these things might become a substantial and integral part of those considerations?

MR. J.E. BAUGH

Yes, I think the Association would clearly support that.

DR. S.B. SMITH

To explore the matter of research just a step further, what about the possibility of trying to eliminate duplication by a little more intensive inter-company planning for research programs to actually gain data and perhaps increase your credibility in the minds of the public by showing what all the companies are doing, and publishing this? This to me seems to be the key. What do you think of this possibility?

MR. J.E. BAUGH

Well, it's perhaps a little hypothetical, Dr. Smith, and it's a bit in error in suggesting that there is no industrial cross-exchange of information, because there is a great deal. I believe you are familiar with the work headed by Dr. Hyne at the University of Calgary, as an example of fully industry-supported research done for the good of a large group of sulphur producing companies.

DR. S.B. SMITH

I didn't mean to imply that there wasn't, and I am aware of the chemical research going on at the University of Calgary. I was thinking more of the research which applies most directly to those problems brought to the attention of these hearings in the various areas by citizens who, I believe in all sincerity, have placed evidence before us that something was not right in their area. Now, about this kind of research that Mr. Naden spoke of and that was spoken of at Whitecourt, about testing of reactions of plants and animals, contained within the legislative requirement that animals and plants be tested up to those standards -- what I was suggesting or asking you, was whether there was any efficacy in intensifying inter-company efforts to pull all this together and let the public know what it's all about?

MR. J..E. BAUGH

I think that would certainly be a useful process, I suppose to some degree we expect government to be the central gathering place of this kind of information; it's generally easier to do it through an agency than it is through a group of companies. I might just cite again Dr. Hyne's work as an example, where the whole question of sulphur emissions become more apparent about two or three years ago. The industries gave Dr. Hyne a special assignment to do a complete appraisal of the sulphur business, from the bottom of the well right through to the

Vancouver ship-loading facility. I think his work has been published. I am sure that he has spoken on it many times; he has reported to the group of companies that financed it. Incidentally, it was financed as an extra research effort beyond the normal budget of the companies in Alberta Sulphur Research, and so I say something is being done, and all of the participants in that work have gained immensely from it. We talked earlier today about the way it has manifested itself in the apparent need for better understanding of the combustion part of the Claus process, and the need to improve the sixty percent recovery at that point in the plan, and a great deal of effort has now been directed to that. So I think industry is busy, though perhaps not on a broad enough scale. I think it's your concern here that we should also be looking at the effect on all of the biological species in the province, and so on. I believe you're right; I believe the industry is prepared and will be doing much more on that as time goes on.

DR. S.B. SMITH

Can I conclude from what you said that you would wish to see all the information obtained by all companies and all the data obtained by all government agencies made freely available to the public without any hindrance whatsoever, then?

MR. J.E. BAUGH

Except for proprietary commercial processes, of course.

DR. S.B. SMITH

But where it was of direct environmental concern, there should be no secrecy in any of these day-to-day reports.

MR. J.E. BAUGH

I'm sure there will be no problem. Our association, I am sure, would be prepared to participate in such an exchange.

MR. W.A. FLOOK

In going over Chaper 4, you have gone to great lengths to re-assert your theme that one type of control standard, namely ambient air quality standard, should be the focus of control. Again the same type of questions come up. First of all, I would like to ask your opinion on the suitability of the present system for measuring ambient air quality. A plant like the Petrogas plant at Balzac has seven mobile monitoring stations located in specific spots. Do you believe that seven such monitoring points constitute an adequate monitor of ambient air quality in the many square miles of area that are subject to the influence of that plant?

MR. J.E. BAUGH

I'm not sure whether seven is the exact number that should be used, but I think something of that order is certainly appropriate. Maybe it should be eight or ten, I don't know. I don't think it should be a hundred, or a thousand, but I believe that something in that order, when used with the other monitoring techniques which we described today, gives an instantaneous knowledge of what is going on surrounding the plant. I would think that it is quite an adequate program.

MR. W.A. FLOOK

It would only give this insofar as they're located downwind in the affected area, and disposed at relatively progressively further distances from the plant. A slight shift in wind, or varying wind, makes the entire monitoring system completely useless until they can be relocated.

MR. J.E. BAUGH

That's true; they are not immediately mobile, they must be moved.

MR. W.A. FLOOK

So that in fact, if the wind veers or backs twenty degrees or so, you could conceivably have your entire monitoring system knocked out of commission until you can relocate it. By the time you have relocated it, conceivably the wind could shift again, so that the only appropriate conformity would be a radical disposition of the monitoring points, probably with some influence to the predominate or prevailing winds fanning out from the plant around a 360-degree conformity. This, it would appear just on the surface, would obviously require many, many more than six or seven points. I would suggest your figure of one hundred might not in fact be inappropriate.

MR. J.E. BAUGH

I think the industry would quake in its shoes if it had to man a hundred stations. I think one point you should put a little weight on in considering this is the very infrequent occurrence of a concentration on the stations that have been located strategically downwind in this same field we heard about this morning. There is a relative infrequency; I don't know the details of the operation of that plant by any means, but Mr. Chalmers certainly made it quite clear that there were very rare occasions when he had any reason for alarm from one of these stations. I know from my own experience in my own company that we frequently leave the mobile station downwind for a month or two months without getting any indication of any kind of a pickup.

MR. W.A. FLOOK

But you're operating now in a manner in which you're supplementing ambient air quality monitoring with point source emission monitoring. You're monitoring your stack as well.

MR. J.E. BAUGH

I think that the industry would continue to do their stack monitoring and their material balance control. I'm sure they would do this, as a good engineering operating practice. We wouldn't suddenly say, "Well, we're not picking up any indications on our sniffers downwind, so we will drop back to eighty percent recovery". I think there's no question of anything like that happening.

MR. W.A. FLOOK

But, in fact, you are objecting to the dual method of control. Control imposed, whether stated in terms of efficiency or stack concentration, amounts to the same thing. It is emission source control supplemented by an ambient air quality monitor, and you seem to resist the concept of the two things; yet in fact it is probably precisely those two things operating together that give you the performance you're so proud of.

MR. J.E. BAUGH

I think the point you miss is that we are also objecting to the degree suggested by the new guidelines by the Energy Resources Conservation Board. We believe that they are adding an unnecessary burden to the industry. They are going to require a group of the plants in the province to put substantial investment in new equipment, plants which have under their present method of operating and with their present equipment, very infrequent, if any, evidence from their monitoring program of violations of the air quality standards -- I can go so far as to say probably never, in my experience. So we have the picture of a nice system that is operating, and we think most of the time it does an excellent job. We do have rare upset occasions, there is no question about that, but monitoring our stack emission, or whatever, we're going to have upsets; we can't avoid them. We have then the picture of a system which is working, which the gentlemen from industry in this room are committed to make work -- they are used to making it work -- and suddenly we have imposed another apparently arbitrary set of rules on top of this, making it even tougher on a system that's already doing the job. So this is what we object to. If, for example, when the Energy Board was approving a new plant and they said, "Well, we have to base our monitoring requirement and our approval for the plant on some recovery efficiency", I am quite sure that the industry would be coming in with recovery efficiencies of ninety-five, ninety-six percent. This is what we have heard the industry can do now, with the Claus process; there's no question about wanting to go back, and retrogress in our approach to this whole problem.

MR. W.A. FLOOK

But you don't want to go up to ninety-nine?

MR. J.E. BAUGH

Not unless it's indicated to be necessary from the monitoring, and if it is, c'est la guerre.

DR. W.R. TROST

I am not quite clear in my own mind as to what kind of emphasis you're putting on each of the three things -- ambient air quality, stack emission control and percent sulphur recovery. The logic of having ambient air quality as the ultimate base for control is of course perfectly evident. But what is less evident to me is the reason that you have for resisting stack emission controls, which I thought were not in fact obligatory on you now, but were a secondary thing that you were doing, and which weren't defined. I don't think you actually have stack emission control regulations, have you?

MR. J.E. BAUGH

Well, we have been issued the new deadlines by the Conservation Board with the program to put them into effect, unless we are successful in applying for a waiver.

DR. W.R. TROST

That's sulphur recovery.

MR. J.E. BAUGH

You were speaking of total emission, or emission control. These two we look upon as being the same thing. They're for any given plant; they're just part and parcel of the same story.

DR. W.R. TROST

But they're really only the same thing in that you need one to calculate the other. Isn't that it?

MR. J.E. BAUGH

Yes.

DR. W.R. TROST

To calculate your percent of sulphur recovery you don't have to have a specific emission control level. You just have to measure it -- it can be anything, can't it?

MR. J.E. BAUGH

Yes, the emission level is the result of applying the recovery efficiency to the plant's throughput.

DR. W.R. TROST

But once you've measured it, you're not obligated by regulation to control it at any particular level, are you, at the present time?

MR. J.E. BAUGH

Yes, I think plants' approvals frequently have maximum limitation on emission as well as minimum requirements for recovery efficiency.

DR. W.R. TROST

Can you tell us what the emission control regulations are?

MR. J.E. BAUGH

I believe, plant by plant, they prescribe a maximum SO_2 quantity to be emitted in any twenty-four hour period to the air.

DR. W.R. TROST

That's in long tons per day?

MR. J.E. BAUGH

Yes.

DR. W.R. TROST

But then you would have to again interpret that to make it a concentration in the stack, wouldn't you?

MR. J.E. BAUGH

Well, perhaps you go the other way. When you recover ninety-seven percent of the sulphur that enters the plant, that leaves so many tons of sulphur that we know have to be going up the stack, and that turns up in so many tons of sulphur dioxide. These are rather consistent numbers in the plant permits.

DR. W.R. TROST

They relate to each other fairly directly. It's not, then, the definition of the number of tons per day that you're limited to emitting, but the actual measurement of the concentration in the stack that leads to that emission; that is the problem.

MR. J.E. BAUGH

It's neither; we say that you could apply either one or the other and have the same results. The fact that there are two doesn't bother us as much as the fact that there is any control of that aspect of the plant operations.

DR. W.R. TROST

Why?

MR. J.E. BAUGH

The reason is the straight economic reason of having all these operating plants in Alberta meeting fairly stringent air quality standards and suddenly having the imposition of these additional types of controls, of the type you and I have just been talking about, which make it, in spite of the good performance, mandatory that we invest thirty to fifty million dollars in the industry immediately with little or no chance of recovery of any of it. You heard Mr. Chalmers say this morning it is a half million dollars operating costs a year to his plant, so it's an economic problem.

DR. W.R. TROST

Is this to meet the projected guidelines? What about the present practice in which you have stack emission control?

MR. J.E. BAUGH

The present practice we are able to live with.

DR. W.R. TROST

Now under present practice -- and correct me if I'm wrong -- you have ambient air quality standards and, if I have understood this paragraph correctly, there are also superimposed stack emission standards.

MR. J.E. BAUGH

Yes, we do.

DR. W.R. TROST

That you're resisting, apart from the guidelines? Are you?

MR. J.E. BAUGH

I think we have given up resistance to the present standards. We have lived with them and everyone now has an operating plant. What we are objecting to is the imposition of additional emission standards on these operating plants.

DR. W.R. TROST

But linked only to the guidelines, in which still higher recoveries are required?

MR. J.E. BAUGH

Yes.

DR. W.R. TROST

And only linked to that?

MR. J.E. BAUGH

Yes. As Mr. Chalmers mentioned this morning, they've increased their recoveries from 92 percent up to 96 percent now, and are living with this. I heard him say that they are prepared to live with it.

DR. W.R. TROST

That's a good clarification for myself in any event. You're really not so much resisting the three things; it's really the improved sulphur recovery that is presumably required of you, although you can appeal against it in the guidelines if it is a problem.

MR. J.E. BAUGH

Yes.

DR. W.R. TROST

In that respect, I think there are figures indicating that a capital expenditure of thirty-four million dollars might be needed in industry to meet those guidelines.

MR. J.E. BAUGH

Yes.

DR. W.R. TROST

But at the same time, quite higher figures have been introduced by the industry. Do you want to comment on those two figures?

MR. J.E. BAUGH

With your permission I would just as soon wait and ask Dr. Hyne when he appears before you here to give his views on that subject. He's the gentleman who has looked into that question of what do we have to do to get a thousand parts per million in the stack gas, instead of ten thousand. We do have two of our expert engineers here available on this question. I'm sorry, the gentleman from Intercom, Mr. Agrawal, is the key man in this question of stack design, and I would like to ask him to field the questions. It's quite a technical section.

DR. W.R. TROST

Mr. Baugh and Mr. Agrawal have had a very interesting discussion of the various plumes already, but I think that part of the problem of stack design does relate to how the effluents from the stack may be dispersed.

MR. R.K. AGRAWAL

That's right, Mr. Chairman. There are a lot of variables not well known yet and not well defined, especially in the Canadian environmental conditions which are considerably different, as we are slowly finding out, from those for which the formulae had been originally proposed.

DR. W.R. TROST

Having read what has been written here, I assume that in what might be called 'standard conditions' stack design problems are worked out in a routine way based on certain formulae. I think your description of these matters is sufficient and there's good experience in them. But how does stack design relate to asymmetrical problems in terms of terrain or meteorology or matters of that sort?

MR. R.K. AGRAWAL

We have started recognizing that meteorological conditions may be quite different from asymmetric plume, as was envisioned by Mr. Pasquill in the Sutton-Lowry formula. In the last two to three years considerable development has been done in order to describe the physics of flow of pollutant within an air field instead of relying on the statistical formulae of Pasquill and Sutton-Lowry. Some of the recent submissions to the government, I can think of Petrogas' submission, did incorporate some of this technology. This technology is being refined in Alberta to the particular environmental conditions here, such as fumigation which we have talked considerably about.

DR. W.R. TROST

Now what do you define as the plume arising from a stack?

MR. R.K. AGRAWAL

The definition of plume remains nebulous. Someone once described it with the ostrich-like philosophy that, "It's something as long as you can see it exists and otherwise we don't know". From the physics and mathematics point of view, it is possible to do away with the concept of plume completely. All you have to do is solve the equations which incorporate the thermal effect of whatever is coming out into the environment, the block of gas, and solve all the equations relating to it in non-isothermal conditions. So far I have not seen anybody do the whole thing together, but we can see it on the horizon. I think within the next two years people will be able to do it.

DR. W.R. TROST

The two parameters that are of interest are first of all the control you might have through stack design on the concentration of ingredients at the stack exit, and secondly, the control that you might be able to calculate, possibly partly through stack design but also in reference to the terrain and other conditions, as to what dilution factors may occur so that one can then calculate the concentration of certain elements at ground level, or at levels where they may impinge on the environment. Do you want to comment on those two briefly, first of all to indicate what the parts per million of sulphur dioxide and other materials might be through stack design principles, in these plants, and then secondly, with further questions on the other point?

MR. R.K. AGRAWAL

The ability to be able to predict the ground level of ambient concentrations, given a stack condition and a set of meteorological conditions, has improved on a large scale in the last two years. The state of the art at this time is such that in a given area with given data, once a history match is done after observed behavior, for example, if we work in Alberta, and if there are two or three plants in which we take all the available data, for as many years as there are, and we study their behavior, then it is possible to back out all the diffusion coefficients which will give you average conditions, worst and best conditions. Those diffusion coefficients, so backed out, can then be used to extrapolate to either new plants or to change plants' operating conditions, like what happens if you put in a higher stack. Effective terrain can be accounted and effective multiple sources, effective transient wind conditions, and certain transient meteorological phenomena like fumigation can be accounted for now much more rigorously than could be done a year or two years ago. However, maybe I can comment on your original question of how low the concentration has to be in the stack, so that you never have vegetation damage on the surface. The question is almost like asking how still the air can get. The air never has zero velocity. For zero velocity air I could conceive that the plume could come intact with only molecular diffusion, and it would have the same concentration anywhere in the path of the plume, but there is no theoretical way of calculating how low the concentration in this stack has to be. We still have to go back to the observed concentrations whereby we can back out what the worst conditions were and they will give us an idea of how still the air has ever been in the last four or five years, and that will give us some diffusion coefficients. It's not possible to calculate diffusion coefficients from the direct method because they are a function of the length and velocity of eddies and the state of the art is not advanced enough that without any knowledge of observed concentrations we can do that, although once you have done that in an area, then it can be extrapolated to the other parts. For example, all the work we have done in Alberta, we've found that the diffusion coefficients for similar conditions turn out to be quite similar whether it's northern Alberta or immediately around Calgary.

DR. W.R. TROST

Let's start at the other end. Say in one plant with a certain system of variables in a particular stack, you produce an effluent at the stack exit that is 10,000 parts per million SO_2. (I don't know whether that's a realistic figure or not.) Can you redesign that stack without affecting the other parts of the plant so as to increase or decrease that parts per million figure?

MR. R.K. AGRAWAL

If I understand the question right, I think the only way to do it would be to add more flue gas to the stack which will increase the velocity of the total effluent going out of the stack, and in turn will dilute the concentration of sulphur dioxide. However, I don't think that that will decrease the ambient concentration -- only to a very minimal extent -- because all that will do is give you a higher plume rise because you have put higher heat load given a higher temperature at the top of the stack, which will give you higher momentum rise and that in turn will give you slightly lower ambient concentrates.

DR. W.R. TROST

Now let's go to the next step. Say you have a plume that at the stack exit has 10,000 parts per million. With what certainty can you calculate the probability that you can get a dilution factor that will reduce that 10,000 parts per million at the ground level or at the environmental impact level to the regulation, which is 1/30,000th of that, thereabouts? I'm really getting at the question I'd asked earlier, about a minimum dilution factor and what probability you can associate with such a dilution factor.

MR. R.K. AGRAWAL

If you have the history in that area, for example if it's a plant which has existed in that area, then we simply have to look at the historical performance of that plant, and then what we do is take some of the worst episode conditions which have ever happened in that plant for the last four or five years, and we'll duplicate that performance and find out what kind of diffusion coefficients existed at the time that episode occurred. With those diffusion coefficients you can change the throughput or temperature at any variable you like and you'll get the corresponding ground level concentration to be expected, assuming the same set of meteorological conditions occurs again. Now the only way we can find the worst condition is to go to historical information like this, for example say that in the last five years the worst fumigation which has occurred has given, say, one part per million or 0.7 parts per million and these are the diffusion coefficients associated with this. All that means is that the top was so low and the air was so still as to achieve this kind of thing. Now we would be able to tell quite accurately what would happen if the same meteorological conditions came around, if the emission rate was different, if the temperature was different, if the amount of effluent going up was different.

DR. W.R. TROST

Now what I thought you were going to describe to me were your systems of calculations that use computers and systems analysis which have certain boundary conditions; you mock up to terrain, you feed in your data and you can get out certain answers. How good were the answers, from your own point of view as a practical and practicing person in this area? I know the models exist -- I'm just wondering if they're any good.

MR. R.K. AGRAWAL

The model results would be extremely good if a certain amount of work had been done before using the models. What you are suggesting, that can we completely and literally predict these things with the boundary conditions and solutions of those equations, there are few variables that are not known. One of the key variables is a set of diffusion coefficients -- how fast you are diffusing in xy direction and what's the z direction. If these things aren't known, I would suggest that your inaccuracy in solving these equations could be considerable. But what the modern practice is and I'm sure all industries are very familiar with this kind of approach in all business, is what's simply known as history match -- you take all the data and analyze them to find out what has caused this, and then use that information which you have just derived to predict the changes in the variables. So when you're talking of a new plant, then in that kind of setup you would have to have some information in that area. For example, if you're talking about northern Alberta, as long as we've done some work in similar environments, similar meteorological systems, if there are valleys, and rivers and mountains, etc., as long as we understand, under chinook conditions, what kind of diffusion coefficients we get when the winds are coming directly through the mountains, then we can start another plant in Alberta and do the job extremely well. But if you are starting without any data whatsoever to match, then I would suggest that the accuracy would be about the same as that of Pasquill or of the Sutton-Lowry method which are empirical and which are varied for certain regions which were tested for certain types....

DR. W.R. TROST

So you're suggesting that you'd have to build your model to the specific case, and after you've built it you'd have to check it against actual checkpoints?

MR. R.K. AGRAWAL

That is right; especially with terrain I think this will be practical.

DR. W.R. TROST

If a person had done such a thing do you think that minimum dilution factors could be achieved?

MR. R.K. AGRAWAL

As much as history you have looked at. Yes, I could tell you that in the last five years this and this has happened, because I've looked at five years of history and minimum dilution factor is so much.

DR. W.R. TROST

It could be achieved?

MR. R.K. AGRAWAL

That is right.

DR. W.R. TROST

I guess we're ready for Chapter 6, Mr. Baugh.

MR. J.E. BAUGH

Mr. Lukacs and Dr. Holmes both contributed to this chapter on monitoring, and we'd be pleased to bring them forward.

DR. S.B. SMITH

This chapter deals with monitoring practices and I'd like to ask a question about Figure 6-4.

MR. J.E. BAUGH

I might just inform the Authority that Mr. Lukacs was responsible for Part A under direct monitoring down to and including item number three, being the ambient air quality monitoring section, and that in addition he did the atmospheric corrosion section. The rest of this section was done by Dr. Holmes. That perhaps may help you to direct your questions.

DR. S.B. SMITH

The question concerns the two determinations which are shown in the bar diagram -- the total sulphation of hydrogen sulphide. The sulphation is obviously dropping very rapidly from 1968 on, and yet for the three years between 1967 and 1971 the hydrogen sulphide is higher in each of those three years than it was in 1967. Only in 1971 is it lower. I just don't understand the relationship here.

MR. J. LUKACS

I'm not so sure that we understand it always either. This graph is based on some forty exposure cylinder stations. These are located around the plant, covering some 40 to 50 square miles, if not a larger area. There are a large number of wells in the area and, as Mr. Chalmers pointed out earlier, the hydrogen sulphide concentration, particularly for some other sources, could be responsible for some readings on those hydrogen sulphide exposure cylinders, and not only the stack alone, so it is very difficult to try to pinpoint an exact trend. We know, though, that overall in the field the total sulphation has definitely been decreasing and so has the hydrogen sulphide. Just exactly what happened in 1968, 1969 and 1970 I really would not be able to tell without going ack to the actual production records in the field. It may be that in 1968 there had been some activity in the field that resulted in some hydrogen sulphide release in very, very small concentrations.

DR. S.B. SMITH

So the total sulphation then is a better record of the ambient air at some distance from the stack, and these three years, 1968, 1969 and 1970, are anomalous -- that's about all you can say, is it?

MR. J. LUKACS

Yes, that's what I would say. I certainly think that the accuracy and the reliability of total sulphation are probably better, particularly because we are dealing with the largest concentration level.

MR. W.A. FLOOK

In describing your monitoring practices, you start off by referring to a daily plant balance; there's a bit of an implication there that a daily sulphur balance is performed by each plant in Alberta. That isn't true, is it?

MR. J. LUKACS

Yes, it is. I think from the very first days of sulphur plants, plants always attempted to perform a plant daily sulphur balance. It doesn't always work out very well, sometimes they produce more sulphur than what comes into the plant, but it always was attempted. It's only limited by the accuracy of the measurements that are involved.

MR. W.A. FLOOK

How accurate is that in fact?

MR. J. LUKACS

It's getting better.

MR. W.A. FLOOK

Would you expect, when each of those big piles of sulphur is finally moved out of the landscape in Alberta, that it will balance down to the last thousand tons -- that you'll get out of it what you think you have there?

MR. J. LUKACS

Well, there are certain....

MR. W.A. FLOOK

I don't want to be facetious, but what sort of error do you think there is in the estimate of how much sulphur is sitting in one of those piles?

MR. J. LUKACS

The daily balance theoretically should be good. Unfortunately, early methods of measuring hydrogen sulphide concentration in the field gas going to the plant, measuring the feed gas rate, weren't all that much of a science ten years ago. Today I would say it's much better, and today sulphur balance could be quite accurate depending on a number of things; for example, how constant the flow rate is to the plant, and how constant the hydrogen sulphide concentration is in the field. It varies from plant to plant; I would hate to give you a number. It depends on the individual plant and also on the individual technician. It takes a very good technician to have a good plant balance, and also it helps if you have a constant stable field.

MR. W.A. FLOOK

But it does also depend on stack measurements that are only performed at rare intervals?

MR. J. LUKACS

Yes, it also depends on the stack measurements; however, two measurements have to be done in order to have a plant balance. The feed-in and the product shown, or the stack effluent.

MR. W.A. FLOOK

Right.

MR. J. LUKACS

Now, if you do all three of them you know what your error is. If you do only two of them then you are happy because you don't know what your error is.

MR. W.A. FLOOK

You assume that the rest is going up the stack.

MR. J. LUKACS

Right. However, today we are doing all three of them, continuously.

MR. W.A. FLOOK

That is a true balance. And it is in fact working out reasonably accurately?

MR. J. LUKACS

I think reasonably accurately it's working out, yes.

MR. W.A. FLOOK

To pursue a little bit more on stack emission measurements, it says, "Determination of the emission rate from a stack using conventional methods involves the measurement of the velocity [and composition, of course]. The test takes eight hours to perform as conducted in accordance with the methods prescribed.... Every effort is made to hold the operating level of the plant steady and at minimum of 90 percent of design". This is not normal operating procedure, is it?

MR. J. LUKACS

Every plant is trying to maintain the operation as steady as possible. Unfortunately, there could be some operational changes. Any change in flow rate will cause certain unsteady conditions in the sulphur plant. The operators try to arrange the tests on days when they know that they will not be doing work on the wells in the field, and they will try to second-guess when the gas purchaser is not going to change the amount of gas they purchase. There are a number of things that can change.

MR. W.A. FLOOK

I realize there's very good reason for doing it that way, but the results you get from it are still not really representative of normal conditions. They're likely to be prejudiced on the good side.

MR. J. LUKACS

No, no. I would like to get this straight. The reason to keep the plant steady is that you get a good measurement, because if you measure the velocity, it takes a number of hours for the profile, and if in the meantime you change the operating conditions you will not get the accurate, average velocity over the eight-hour period to match the average concentration in the stack. This is the only reason why we should maintain it at a constant level. It affects the accuracy of the measurement, change in plant operation, not necessarily the emission from the stack. If you are inferring that just because of changes in the plant operation the emission is going to be always higher, not necessarily.

MR. W.A. FLOOK

I am inferring something like that, yes.

MR. J. LUKACS

The change in operation could cause reduction in sulphur dioxide.

MR. W.A. FLOOK

It could cause fluctuation.

MR. J. LUKACS

Yes, short or long depending on the kinetic and equilibrium reactions in the sulphur plant.

DR. W.R. TROST

When you set up your monitoring systems, whether they're continuous or integrative or cumulative, how sure can you be that you get the bad spots?

MR. J. LUKACS

Well, you try hard to get the bad spots. There are a number of considerations that one takes into account to determine the postioning of trailers. We try to describe it in the submission; one of them is the total sulphation. We have a network of total sulphation cylinders around every plant. Now these total sulphation cylinders, although they are not instantaneous readings, give a very good picture month after month, year after year of the areas in which the highest concentrations occur. Then we take the general wind direction. We look at the topographical features. We take complaints, if any, or remarks by the people in the general area and of the operators who work in the plant. By using the best judgment, then, one is putting the trailer out and then sometimes a trailer is moved. Some plants will have more than one trailer, or a plant will use only one trailer; we move the trailer to different locations from year to year to try to set up a statistical history, to try to get a diverse situation. There is no guarantee, however, that it is. It is only with some techniques that Dr. Holmes is going to describe here and some other plume-chasing techniques that we can really ascertain that the trailer will be located at the worst possible location. Technology is advancing today in leaps and bounds, and I think we may have been short of it in the past in trying to find the best locations, but I can almost assure you that within the next few years we will be able to almost exactly pick the worst spots around sulphur recovery plants.

DR. W.R. TROST

It is becoming more possible to contour your location to indicate where bad spots and presumably good spots may be? But this hasn't necessarily been the case in the past?

MR. J. LUKACS

It has been in the past, using the exposure cylinder stations. With newer technology, newer instrumentation and more sensitive instrumentation being available now I think we will be able to do better in the future.

DR. W.R. TROST

I know that this is a general presentation and so it has nothing to do with specific cases, but it's easy for me to say that the submissions that have been made to us in other places sometimes indicate that the bad spots weren't picked, and I'm just trying to find out whether it was by accident....

MR. J. LUKACS

It is possible but I would like to submit to you that we all can be biased, and when I go out there as a technical man I try my best to pick the best place. Somebody who lives in the area and has a personal interest in the area, without looking at any technical justification, can quite easily make the wrong assumption that the location was picked, purposely the wrong location.

DR. W.R. TROST

Now, if a measurement -- and let's say it's a continuous monitoring device -- indicates that the standards are undesirable, how long does it take to exercise control in the plant?

MR. J. LUKACS

It all depends on what mode of monitoring we have. In a case like Petrogas and a few other plants in the area, where the readings are telemetered to the plant, it's only a matter of a few minutes.

DR. W.R. TROST

Now, what inertia might there be in the system? That's to say, how much material might get out, after the signal has been given, that is perhaps undesirable?

MR. J. LUKACS

This goes back to the plant operation, and once again every plant is a bit different. It depends a bit on the size of the plant and the physical setup of the individual plant; I am really not qualified to say whether it takes an hour or two hours to make this change. Smaller plants could make it quite easily, and for other plants very large, changes may be a little bit slower.

DR. W.R. TROST

It is a problem but it relates to specific plants and other factors. Right?

MR. J. LUKACS

As far as I can tell, yes, but I may not be qualified to answer that question.

DR. W.R. TROST

The slide that had been on the screen a bit ago indicated a history of considerable improvement over the last four years or so in total sulphur emission, and I'm sure that improving trend is out for a longer period of time, perhaps over the whole period of time in which the plants have been operating. Do you want to comment on that improvement trend -- how the monitoring system responds to it and what you see for the future?

MR. J. LUKACS

I would not want to go back ten years and extrapolate the records back and tell you that in 1962 the readings were 0.8. I would hesitate to do that; as a matter of fact, I have looked at a few plants and this was not the case.

DR. W.R. TROST

Do you know what the case was?

MR. J. LUKACS

The case was that the concentrations started at the lower level and increased around 1966-1967-1968 because the plant increased -- the emission increased. It started to decrease again with improvement in process control. I don't know if I can speak for C.P.A., but from what I have seen in the province and have seen working with the gas processing industry, the gas processing industry has made a tremendous effort in the last four or five years, particularly since the technology is available to measure and monitor what the industry is doing. I am referring particularly to the process now. It wasn't a very long time ago when it was very difficult for a plant operator to know really what his plant was doing. The sulphur recovery industry in Alberta is fairly young. And there was a lack of analytical technology from the start of the operation until such time as we have managed to develop techniques that now can tell the operators what they are doing. Once the operator is given the right information he is able to make the right corrective actions. The industry has put through quite a few corrective measures, as Mr. Chalmers pointed out this morning, and I think the industry is going to continue on this road.

DR. W.R. TROST

Now a part of the story of the development of new monitoring systems has been the feedback of that information into the control of the plant. Is this part of your presentation,Mr. Lukacs, or should we....

MR. J. LUKACS

Yes, I think that the telemetering end of it is covered here.

DR. W.R. TROST

Do you want to then comment on the feedback part, on the part in which you used monitoring inputs to control plant operations?

MR. J. LUKACS

Any specific questions, or just in generality?

DR. W.R. TROST

In a general way, particularly in respect to short-term future developments in this area.

MR. J. LUKACS

If I understand the question right, the concept of the ground level monitoring control program is not quite new. It has been tried by other industries at other places, particularly when the industry just could not economically reduce the emission, and they has to resort to this type of approach. It has been done successfully to my knowledge at other places. I think the Petrogas case proves that it is feasible, and that it can probably be done with a reasonable number of monitoring stations. And, a comment on some of the earlier questions. The seven monitors in the case of Petrogas weren't just picked out of the blue; I think they have been placed by considering the area very carefully, considering the topography of the area, the general wind directions, and the iso-concentration maps of total sulphation. So one can in a semi-scientific fashion determine a reasonable number of monitors that can help to monitor the ground level concentration resulting from one single operation. It is statistical measurement.

DR. W.R. TROST

The sixty-two or sixty-seven sulphur extraction plants in Alberta, whatever the number may be, are all of them now using instantaneous feedback from monitors to control plant operations?

MR. J. LUKACS

To my knowledge there are three or four larger plants in the province, but I would like to add to this a bit more. I really don't see why all sixty-seven plants would have to do this.

DR. W.R. TROST

Elaborate.

MR. J. LUKACS

Our sulphur plants in Alberta are operating under certain sets of regulations. The stacks are designed to meet certain ground level concentrations; it is a matter of opinion, and some of us feel that these design concentrations are conservative and allow for a certain amount of safety factors. The plants have to meet certain efficiencies. They cannot put out more sulphur dioxide than called for by regulations, and in addition to that in almost every plant you have to do some kind of monitoring of the air quality in the area of the plant to ascertain at least historically whether the air quality has been exceeded in the past, so although there is no instantaneous feedback there is a record of the ambient air quality around every plant in the province.

MR. J.E. BAUGH

Mr. Chairman, with your approval we would like to introduce some additional evidence in connection with the line of questioning you remarked on yesterday, dealing with actually two things. First, with the material balances that are run on the gas plants in Alberta and the reporting of this information to the appropriate authorities, we felt that perhaps we didn't come quite clear on what this practice is. Second the question of the concentration of SO_2 within the plume, and in this regard we would like to have Dr. Holmes speak to the Authority on his portion of our submission. Finally, we have a representative of a member company of the Association, which company has actually helicopter flown and sampled the plumes at several of their gas plants. He doesn't have a lot of quantitative data with him, but he is prepared to come forth and tell the Authority what observations they made through that procedure, and we think it is quite interesting. Mr. Lukacs, would you please tell the Authority what the current practice is in the province with respect to plant measurements and reporting to the authorities?

MR. J. LUKACS

To my knowledge, every plant in the province performs daily material balance, and this material balance is being reported to the authorities, the Energy Resources Conservation Board, and to the Department of the Environment. This has been done at least going back to 1962 -- my earlier days in the gas plant. In addition to daily reports, every plant submits a monthly report, which summarizes the monthly operation of each plant and the total monthly material balance. If I am correct, this report is forwarded to the Energy Resources Conservation Board.

DR. W.R. TROST

Is the daily one forwarded too?

MR. J. LUKACS

Yes, to my knowledge, both to the Energy Resources Conservation Board and to the Department of the Environment.

DR. W.R. TROST

That daily material balance -- in what form is it cast?

MR. J. LUKACS

The daily material balance follows a standard form, if I am correct, which is designed by the Energy Resources Conservation Board.

DR. W.R. TROST

So it shows the nature of the feed to the plant?

MR. J. LUKACS

Right.

DR. W.R. TROST

And the various take-out points?

MR. J. LUKACS

All the relevant questions here are on a standard form.

DR. W.R. TROST

Now in respect of the emission, does it give both the tons out as well as the parts per million in the effluent, which is the point Mr. Baugh was speaking about?

MR. J. LUKACS

I would say, only the tons.

DR. W.R. TROST

Is a record kept of the parts per million concentration in the stack at the exit point?

MR. J. LUKACS

As of today, those plants that have continuous emission monitoring systems, do have a record of the parts per million in the stack on a daily basis.

DR. W.R. TROST

Do most companies have that or can you tell me.....

MR. J. LUKACS

Yes, about twenty-five out of the thirty-nine sulphur recovery plants required to put in continuous mass emission monitoring have this record.

DR. W.R. TROST

Now in the case that the company doesn't actually measure the concentration in the effluent at the exit point, how do they calculate it?

MR. J. LUKACS

Every company has to measure the concentrations. You don't have to calculate the emission.

DR. W.R. TROST

You mean if they don't do it on a continuous basis, if they do it some other way?

MR. J. LUKACS

No, every company has to measure it on a continuous basis. That is the only way one can calculate the mass emission -- on a continuous basis.

DR. W.R. TROST

Didn't you just tell me that some did and some didn't?

MR. J. LUKACS

I'm sorry. According to present regulations only plants that are designed for one hundred long tons per day capacity, or that emit sulphur dioxide in excess of ten tons per day, have to measure the emission on a continuous basis. The smaller plants don't have to measure emission on a daily basis. They calculate it based on production numbers -- the sulphur into the plant and the production, by difference.

DR. W.R. TROST

We were interested in typical parts per million concentrations of SO_2 in the plants, knowing it varies from one to another. Can you give us typical figures?

MR. J. LUKACS

Better plants would have seven thousand, eight thousand, nine thousand; some plants designed in a different fashion as that have more difficult inlet streams of sulphur may have 15,000 ppm in the stack. It also depends a great deal on the dilution factor in the stack. Some stacks are designed to allow more dilution than other plants. The concentration in the stack is a bit deceiving. One may be able to dilute the stack concentration from 15,000 to 10,000 with a tremendous amount of expense and waste of energy. Yet that type of dilution really doesn't buy us anything once the plume gets into the atmosphere -- or buys us very little. The return on that type of energy is very small, particularly when we look at the next example; the natural dilution in the atmosphere is very sparse and very efficient, so the matter of diluting the effluent in the stack is probably the most expensive if not wasteful practice.

DR. W.R. TROST

Is the concentration of SO_2 in the stack subject to natural variability through routine plant operations, or does it tend to remain at a relatively fixed figure?

MR. J. LUKACS

The concentration in the stack does vary to a small extent due to such things as draft through the stack, ambient temperature and wind conditions, but particularly it relates to the plant efficiency, the efficiency that the process can achieve. The stack volume stays reasonably constant.

DR. W.R. TROST

Could the concentration of the emission gases at the exit point be used as a control device on plant operations, whether or not they have any utility in respect to environmental effects downstream, or outside the plant?

MR. J. LUKACS

There are so many factors in the operation of a sulphur plant that I would very much hesitate to recommend using the stack concentration as a control device. It's an indirect indication, certainly not a control too.

DR. W.R. TROST

Isn't it a much more direct indication of the plant efficiency than ambient air measurement outside?

MR. J. LUKACS

Yes, I would say that by the time the sulphur dioxide gets to the ground level there are several other factors that enter into it, so I have to say yes, it's a more direct indication.

DR. W.R. TROST

Does any of the companies actually use the concentrations of the emission gas as a control element?

MR. C. LUKACS

Not to my knowledge.

DR. W.R. TROST

It would seem to me it would be a set-up for it.

MR. J. LUKACS

Yes, Mr. Chairman, they are set up for it; they are set up to measure the emission because of a regulation, but it is not an operation control device. It is an emission-monitoring device to see how the plant is doing with the gas regulations.

DR. W.R. TROST

Right. And I still have the same view. Returning to the second point that you made, granted that under certain circumstances the amount of mixing that one gets in the atmosphere is large as compared with what one might get by pushing additional air through the stack. There nevertheless seem to be occasioned in which that desireable atmospheric mixing may take place for a variety of meterological and terrain facts. In such a case would emission control at the stack level not be helpful?

MR. J. LUKACS

The dilution in the atmosphere, the turbulence in the atmosphere, is a matter of degree. There is always some turbulence in the atmosphere. Under any circumstances the dilution in the atmosphere is much, much more efficient than any dilution we can ever achieve in the stack itself.

DR. W.R. TROST

Yes, I think that goes without saying, but can you answer more directly the question I put to you?

MR. J. LUKACS

To answer your question, it is trivial that if you are able to cut the concentration to half in the stack itself, that two miles down from the stack it will have some effect. I am not quite sure what effect the degree of control is going to have at the point of impingement.

DR. W.R. TROST

Is this the kind of problem that is subject to calculation in the models, and we would here be thinking of the models in which minimum turbulence existed? Then your input would be varying the parts per million in the effluent as it leaves the stack. Would your model then give answers that would indicate what the effect at ground level might be?

MR. J. LUKACS

I don't quite see the point of the question. Certainly, in any model, in any calculation, the concentration in the stack is always one of the main factors. When we calculate the ground level concentration at any one single point, there are many other factors involved, and this is why last night I wasn't quite sure whether I had the minimum dilution factor calculations as such. I have done many, many calculations -- calculating the concentration at any one point in the plume on the center line, or fifty feet from the center line, or two dozen feet from the center line at various distances from the stack. Calculation is one thing; what we actually have in practice is another, and I wouldn't want to put my life on these calculations.

DR. W.R. TROST

Well, it may be that under extreme circumstances other people might have to put their life on the line in some of the things we are exposed to, according to evidence that has been put before us. I'm just trying to follow this thought through; if the gas is emitted from the stack exit and it has a certain concentration and through a combination of circumstances it doesn't mix freely, but in fact comes down to the ground level still containing gases that are undoubtedly diluted as compared with the stack effluent situation but still are potent enough so that they can cause severe distress to, or perhaps knock out an animal or a human being -- and there has been evidence submitted that that has happened intermittently.-- I'm trying to clarify that particular kind of an incident. It was in connection with that kind of a possibility that the question of minimum dilution factors were being discussed. Apparently, a minimum dilution factor, if it were calculated, would indicate whether or not such a situation could occur. Now what would the concentrations in that cloud, or that plummeting plume, that temporarily captured gas effluent have to be to bring about these results? I don't think we have testimony on that, but the question is, can that circumstance be avoided by controlling the parts per million in the stack to a figure not as high as ten thousand? That's the question I'm trying to find an answer to.

MR. J. LUKACS

If an incident like that can happen at all, which I, myself doubt, then that situation could be improved by reducing the concentration in the stack. I would like to go back to the first part of my answer, though; I have some personal experience with plumes. I have myself sampled plumes with helicopters, and there is no question that the dilution is very, very fast in the atmosphere. I would very much doubt that one mile from any stack at ground level, that concentration could be so high that it could adversely affect a person, particularly because I have had the occasion to inhale full concentration of this type three feet from the stack, and it did not knock me out either. I have been climbing stacks and sample stacks that were under positive pressure, and the power plate just happened to be in such a direction that we had to stand downwind from this power plate, and we had to do the test because it had to be done, and I did the test myself. In order to do the sampling and the velocity measurement I have had occasion to inhale this very high concentration which is in the stack, and I have worked under these conditions for a matter of a few hours and it did not knock me out.

DR. W.R. TROST

I'm really asking whether there is a model in which you can put figures, and get out answers.

MR. J. LUKACS

The question is a very difficult one. I think there has been testimony that most of the models that we have today will work only under ideal conditions, and then assumptions that we necessarily have to make for these models will hold. If these assumptions don't hold the model calculation doesn't mean anything. However, there are some measurements such as the ambient air quality monitoring trailers, and other measurements such as helicopter and airplane surveys, made in the province that will indirectly, or maybe directly, will tell us what the minimum dilution factor is. If I may cite another occasion that you may be aware of, a situation in Edmonton. Edmonton Power downtown has caused quite a bit of concern over the last few years because of downwash problems from the stacks, particularly prior to the extension of the three larger units. There were days during the winter when traffic on the bridge west of the power plant had to stop because of fog or because of water vapor that was carried down by downward currents from the stack. It was at the time when the building was 220 feet tall and the stacks on top of it were only a matter of another 20 to 30 feet, and we have set up monitors right next to the building, right on the road and right between the building and the Terrace Building, less than a thousand feet from the stack. We have never measured concentrations under worse conditions, and I think it was probably very good to pick the worst days; we spent a whole winter there. We never measured concentrations

higher than 0.6 to 0.7 ppm, less than 1000 feet from a very short stack, when the plume was directly brought down to the ground level and the concentration of the stack was in the order of 300 parts per million. That's right there -- a dilution of about five to six hundred, within 1000 feet of the stack. Now, these are the types of things we have information on, but there is no way that anybody, as far as I know today, can with any certainty predict this type of concentration or this type of condition, better than an order of magnitude.
In addition to the material balances, every month, each plant submits air pollution monitoring reports to the Department of the Environment and the Energy Resources Conservation Board that cover all air quality monitoring that has been done in the area of the plant. So there is in effect a very rigorous reporting by all the plants to the authorities.

DR. W.R. TROST

Is there a feeling in industry that there are sufficient points being monitored outside the plants?

MR. J. LUKACS

I don't know how industry feels; I feel this is probably sufficient.

MR. J.E. BAUGH

The Authority has indicated interest in the question of the concentration of SO_2 within the plume, and what is the worst situation that we might expect within the plume. I believe that some of Dr. Holmes' techniques and his approaches to this plume monitoring might be of interest to the Authority.

DR. R. HOLMES

Later on today in other submissions I would like to talk very directly to this topic in connection with some other submissions, and I would like to defer some comments in this regard to those submissions. However, may I recite a bit of history at this time regarding the evolution of our present knowledge of plume structures, atmospheric structures, plume behavior, etc. I remember hearing a student of Pasquill give his talk on some of the early work that Pasquill performed which led to his final devising of his equations, and also Mr. Lowry and the students of Pasquill, a student of Sutton's work and many others who have done enormous amounts of pioneering work. Our present techniques in measurement are in some cases very sophisticated, and we owe many of them to the existence of the space program; were it not for the impetus and the power that was put into technology by the space program we would probably have far fewer measuring techniques than we now have in most environmental and resource sciences. This is very recent, so the men who made these models and based them on very sound principles had to do so without the benefit of confirming data. I must tell a short story that was told by Von Carmen, who is also a very notable figure in vortices that are created around the orifice of the stack. He was talking to a graduate student, and said, "Young man, I want you to remember that there are two very, very difficult fields in environmental work. These are diffusion and radiation. Now, when you die, if you are a very good man you will go to heaven, and when you pass through the pearly gates God will tell you all about radiation." This sometimes causes difficulty in trying to understand diffusion as opposed to other very difficult things. Because the atmosphere is a very dynamic thing our present knowledge tends to indicate that the structure of the atmosphere is very much in parcels, and modern atmospheric physics tends now to get the atmosphere to predict its behavior in terms of parcels. Measurements from the ground using towers, and measurements from helicopters and aircraft, tend more and more to confirm the evidence that the atmosphere acts in parcels, and each of these parcels has a peculiar set of properties. Determining how fast atmospheric entities move up and down and sideways is merely a matter of determing the characteristics of each of these individual parcels as they pass by a point. An air mass composed of parcels -- an air mass is nothing but an enormous parcel of air with its discrete characteristics. We have to thank the Norwegians for this kind of knowledge. So we have a large Arctic air mass and it butts up against another air mass, and the reaction front between the two air masses produces a zone, but these parcels behave adiabatically and they (more or less); maintain their discrete characteristics so when air then confronts the end of the stack, it merely picks up (aside from the interference of the stack itself) the effluents coming out of the stack and carries them within its existing parcels. It carries them downwind. These parcels have shape, they have behavior characteristics, they have structure, and they carry this effluent downwind as they go. Now, as the air travels, depending upon the distance between the parcel being examined and the ground, it derives its properties from the ground. If the ground is hot compared to the air that heat transfers into the air; if it is moist compared to the air,it transfers the moisture into the air and vice versa. So the attempt of Pasquill to apply pure statistical theory to plume or diffusion was singularly unsuccessful because he had no confirming evidence, no confirming data or observations to give him the opportunity to jazz up his equations to make them fit better. So, with a lack of all of this information -- there is just a pittance of data to substantiate how air behaves over ground as it passes from a gas plant over an urban area, over an agricultural area, over an irrigated area, mountainous terrain, foothill terrain, it's impossible to substantiate most of the statistical theories. In the absence of these data, we have involved ourselves over many dozens of years trying to make the statistical equations work. When the conditions of air passing by the stack seem to be more Gaussy -- and an atmosphere tends to be very non-Gaussy -- if it approaches 'Gaussionality' (how do you like that one?) when the structure of the atmosphere, the temperature, the lapse rate, etc. are just right, then the equations start to fit. This is more likely to occur when the air has a lapse rate, its adiabatic lapse rate, when it's over smooth terrain with relatively homogeneous surfaces underneath. The less homogenous it gets, the more non-Gaussian it gets, and so-- and my colleagues and I have discussed this point at many times -- the tendency now (under conditions like this) is to try to leave statistical methods entirely, because they do not represent real conditions. Nature does not behave that way. It tends to under some conditions as I have just mentioned, but the tendency now is to derive mathematical models that are physical, based on physical principles that use diffusion theory, not statistical theory to predict the behavior of effluent and plumes downwind. Now, you are trying to predict a plume and its concentration of effluents downwind as it passes an urban area. The thing which has more to do with plume behavior over an urban area is this urban heat island effect the roughness parameters on the ground. There are no measurements of this; we can devise equations and statistics to our hearts content, and they don't tell us very much about what the plume will be like as it encounters an urban area, or as it encounters an area of severe roughness, or inhomogeneities due to water content or heat content of the ground. Nevertheless, it is the only way that we can ever attempt to have any kind of fruitful or beneficial method of predicting plume behaviors by using these physical models (not statistical ones) supported by an enormous amount of real data, real observations of plume behavior. It is just in the last few years that this has been possible, using helicopter techniques, aircraft techniques, and airborne techniques of all kinds. They use kites and they get them up in the air and string their thermistors and temperature and humidity sensers up and down the wire; they use tethered balloons, all kinds of airborne methods, to get into the air mass where the thing is and to determine its characteristics. Then you can validate or invalidate a model, such as might be the case. We are trying to develop, to as high a degree as methods will allow, a method using what is called a correlation spectrometer. Correlation spectrometry is very old; it is not a new technique. However, its application to airborne work is rather new, so we have a rather fussy optical system that takes ultraviolet light and routes it around the periphery of an airplane -- from the cabin, to the wingtip, to the tail, to the other wingtip and back into the cabin again. Trying to maintain all these mirrors in proper focus is a bit of a task, but if you can get ultraviolet to pass around this path, the correlation spectrometer can detect the amount of SO_2 in that path, and this type of thing, either in a helicopter, or an aircraft, or some other device in which you can get up into the air and move about within the air mass and encounter parcels of air and the actual conditions that exist there, tells us the absolute concentration of SO_2 (and in this case, NO_2) in the plume, wherever the aircraft might happen to be. There are restrictions of course as to where the airplane can go. You can't fly down 16th Avenue; you've got to maintain a certain legal altitude, so it restricts our measurements in that regard. Over agricultural land we can fly in some places at 30 or 50 feet; we can't get much closer than that so the gas that is underneath the aircraft of course is not included in the measurement. Plume behavior is a subject that has occupied the minds of hundreds of scientists for many years. I was once involved with Paul Kramer from the United States which is now NOA or ESA in trying to arrive at the coefficients of diffusion, C sub xyz, from plume dimensions and plume measurements per se. We photographed thousands of plumes over industrial areas and the dilution factor associated with the most concentrated plumes was 15. That's a very concentrated plume, and this occurred under land breeze - lake breeze situation on Lake Michigan. We were trying to define what would happen if a nuclear accident occurred at a power plant, so when the air comes off the Lake it is very smoothly structured, parcelized, very, very even, almost laminar flow. I would like to show a slide. From the U.S. Navy we got a smoke generator that used to go in the back of battleships; a battleship used to get about three of these and start them up to make smoke at sea for camouflage. We sent this thing up the plume -- that tower is about 350 feet tall; I used to climb it three times a day and tend the instruments up and down the tower to determine atmospheric characteristics -- and you see the smoke on this particular day when the air flow from the lake to the land was very smooth, almost laminar.

This had a dilution factor of 250; you can see that the turbulence is eating away at the edges of the plume and you can see the very highly parcelized structure to a plume like this, but this plume maintained its integrity for 40 miles in just the same shape you see it now, with a dilution factor of about that much. Next slide.

This is the plume again from about 30 miles from the tower where it was emitted. Wind shear was beginning to make the plume wander in kind of a fan meandering pattern, but when you get dilution factors of this nature you have a danger of very severe fumigation problems. Next slide. Here I am at the orifice of the stack looking right down the plume; we're in a condition here where the inversion is capped off the top, so until the inversion was burned away, it meant that the plume had to stay within it, or underneath it unless it was ejected through it by the simple thermoplume rise. The turbulence began to eat away at the bottom of the plume and eventually carried it to the ground or the lake as it wandered up toward the northwest in this picture. Next slide.

This is a looping plume, not a very pronounced one, but it is a looping plume. It tends to follow these buoyant parcels of atmosphere of varying heat content. They rise and they fall, based on how they are jostled against each other and how they are carried, and you can see the plume tends to go this way. When that plume comes to the ground, the concentrations are very, very dilute; the dilution factors in a plume like this would approach 5, 10, 15 thousand. Next slide.

This is a fanning configuration. Somebody way down in Southern Alberta was flaring off some stuff and this plume maintained its integrity and a fanning configuration for -- well, this was near Foremost, and it was well beyond Medicine Hat before the plume became relatively invisible. It was ejected between two inversions; it wouldn't come to the ground because of an inversion at that point, and it wouldn't go any higher because of another inversion layer there. It stayed in this layer, a rather unusual rare situation, just fanned out in this inversion layer, and moved slowly downwind with the general air movement. It's possible to show hundreds of different kinds of plumes to give a better feeling, but it's necessary to understand how a plume behaves. It is necessary to have an understanding of how the atmosphere behaves because the plume goes where the atmosphere takes it. Dilution factors which we have measured from gas plants are in the order of five to ten thousand, assuming that the concentration at the orifice would be in the order of ten to twelve thousand parts per million.

DR. W.R. TROST

You're suggesting that there is (for a variety of reasons)a good deal of variability on the actual amount of dilution that may occur to a particular....

DR. R. HOLMES

An enormous amount.

MR. J.E. BAUGH

We will have more on Chapter 6 later. We are now available for questioning on Chapter 7.

DR. S.B. SMITH

Dr. Hyne, there are a couple of points that perhaps you could clarify for me since I am not a chemist or chemical engineer. One of these is with respect to the first chart you show in Chapter 7, where you show the proportionate representation of the effluent N_2. Now, is this always N_2, or is it NOX? What is it in terms that I could understand?

DR. J.B. HYNE

Well, that's the four-fifths of atmospheric air that is not oxygen. That's the nitrogen in the air; it refers only to that.

DR. S.B. SMITH

In the concentration problem which is shown you are dealing only with the facts as you have to deal with them in attempting to get the right proportions in your burning process. You're not concerning yourself with oxides of nitrogen here at all? Can you identify for me from your knowledge oxides of nitrogen in the stack gas?

DR. J.B. HYNE

What is being focused on here is the concentration problem. In the worst possible cases in any gas plant, it would be impossible to see in terms of sickness the concentration of oxides of nitrogen from any source on this diagram; they would be so very, very small. The depth of that block of nitrogen represents millions and millions of cubic feet per day of throughput, whereas in the very worst conditions I would imagine if there were several hundred cubic feet of oxides of nitrogen passing through the system it would be an unusual circumstance.

DR. S.B. SMITH

So, the answer that you're giving is that the dilution factor is so enormous that these oxides of nitrogen which may be formed because of the high proportion of nitrogen in the atmosphere are not dangerous in the stacks.

DR. J.B. HYNE

I don't think it's the dilution factor, I think that in the gas plant potential sources of oxides of nitrogen are very, very limited.

DR. S.B. SMITH

There just isn't enough oxygen?

DR. J.B. HYNE

No, there's not enough nitrogen that's easily convertible to oxides of nitrogen.

DR. S.B. SMITH

Mr. Chalmers mentioned that they had been to 98 percent with what I presume is a three-stage Claus. And yet in the concluding part of your Chapter 7, you suggest quite strongly that 97 percent is post-optimum and it isn't likely consistent to go above that, or for great lengths of time. I can't recall the exact words you used, but I think that is the essence of it.

DR. J.B. HYNE

Well, far be it from me to discourage Mr. Chalmers from trying to keep it 98 percent all the time. I would like to say one thing before answering your question, because I think it's crucial to many other calculations and projections that might be made regarding the efficient operation of the gas processing plant. If it is mandatory that you achieve a certain percentage, let's say 98, there is no way that it is going to be attained in a plant that is designed to attain only 98 percent. There must always be a buffer in the design capacity above the conversion efficiency required. On the difference between my suggestion of 97 percent and Mr. Chalmers' figure of 98 percent, if I could have the slides, the one on temperature. By far the most important fact determining the efficiency of a Claus process is the temperature at which it's run. Now there are various other factors such as front-end reaction furnace, conversion efficiency, the efficiency of the catalyst, the space velocity in the reaction chambers, etc., but there is one thing that you can never exceed in the Claus process and that's the thermodynamic equilibrium that is defined essentially by this curve. Now, as you see, 98 percent, is way over on the left-hand side of this curve; that 98 percent is at a very low temperature. So of course you say, "Why don't we just keep going to lower and lower temperatures to get closer and closer to 100 percent?" The problem is that sulphur melts where it's shown, and if you go down below that value in order to get very high efficiency, then you no longer have sulphur in a form that can pass through the system. It is a solid, and becomes deposited on the catalyst. So, this is the limiting factor, unless you are prepared to have solid sulphur deposited in your system and then put that section out of service for regeneration; one tail gas cleanup process now available and operating in Alberta does in fact, just this. But it's obviously an expensive system, and remember this is cleaning up the tail gas, which is only three percent of the throughput, not processing the other 97 percent. I would shudder to think of the physical dimensions of a plant with four reactors on, two in regeneration, if it was handling four or five thousand tons a day of sulphur throughput. That's a rather long-winded response to your question as to why I say 97 percent and Mr. Chalmers suggested 98 percent -- that you're working right on the threshold of practicality.

DR. S.B. SMITH

In your estimation can the cost of keeping the clean air effluent coming from the processing plant be held down in the initial design stage then, rather than in trying to modify this design after the plant is in operation? Presumably the Petrogas plant must have been designed for a very high recovery rate, because it's achieving that.

DR. J.B. HYNE

Whoever designed the Petrogas plant 'way back in the early sixties should be complimented for his foresight. Obviously it put the company in a very strong position. On the question of minimizing effluent by maximizing the initial design, as opposed to adding on, like many other things I think it's a situation that we must live with; we have it now, and we've simply got to live with it. If the effluents from sour gas processing plants are to be reduced to less than 1 percent -- 1/2 of 1 percent, 1/10 of 1 percent -- then almost certainly this is going to have to be done for the foreseeable future, either by rather ingenious in plant modifications, such as were hinted at by Mr. Chalmers, or by tail gas cleanup add-on. As was indicated earlier on in the C.P.A. presentation, the cost of these tail gas add-on units increases exponentially with the cleanup level that you demand. It's not a linear relationship; it's an exponential one. I think it's only fair to say that the technology is available to get down to one part per million. Of the public (because that's where the final bill is going to finish up, through the price of the gas -- I don't think we need worry about the price of the sulphur) is prepared to pay the enormous price for going down to one, two, three parts per million, the Stratford process is capable of doing this.

MR. W.A. FLOOK

Since we're all very interested in these last couple of percents of efficiency in the process, could you explain a little more about the role of CS_2 and COS in limiting the effectiveness of the Claus. How do they arise, and what limitations do they impose on the potentiality of the Claus process, and why indeed does tail gas cleanup become almost mandatory?

DR. J.B. HYNE

Figure 72 is the one that I'll be really talking about. The problem with COS and CS_2 is that no tail gas cleanup process in operation today has an inherent capability of removing COS and CS_2. The COS and CS_2 that are presently in tail gases go up the stack and out into the atmosphere as SO_2 because the COS and CS_2 in the incinerator are burnt to carbon dioxide and sulphur dioxide. So this is the problem. Whatever tail gas cleanup process now commercially available that you put on the tail gas of a sour gas processing plant, the absolute minimum level that you could possibly attain in the effluent from the tail gas cleanup could not possibly be lower than the COS, CS_2 content, because you don't remove them. How high are the COS and CS_2 levels? They're normally in the thousand parts per million range; in some operational systems in Alberta they run as high as 6000 parts per million. This means that even if you had a 100 percent efficiency in SO_2, H_2S cleanup you would still have 6000 parts per million of sulphur in your tail gas, simply because of the COS, CS_2. It is primarily formed in the front-end reaction furnace although, as we heard when we were discussing downhole sulphur plugging and its removal by CS_2 squeeze, even with the most efficient recovery in the plant there is bound to be a little carryover of the CS_2 that's being used as a squeeze. This will tend to be in shorts, because obviously you are not squeezing the whole all the time. The principal source of COS and CS_2 is through the combustion of the small approximately 1 percent carry-over of methane from the ammine stripper. This wasn't detailed in the brief, but the H_2S is removed in order to produce residue sales gas. Since it is absolutely mandatory that you always run on the safe side -- in other words that there is no H_2S in the sales gas -- there tends always to be a little methane carried over into the H_2S. This means that your front-end reaction furnace contains carbon in the methane. This burns with the hydrogen sulphide and oxygen and you get COS and CS_2 from it. It's formed there; it's not converted to any significant extent in the Claus catalytic beds, although if you intend to run them hot, as Mr. Baugh mentioned yesterday, you can achieve some hydrolysis of COS and CS_2 converting it to carbon dioxide and hydrogen sulphide. It's formed essentially in the front-end reaction furnace, and it isn't removed by currently available technology in the tail gas.

MR. W.A. FLOOK

And if you could keep carbon out of the feed to the front-end furnace then there would be no possibility of formation of these carbon-containing compounds?

DR. J.B. HYNE

Yes, the major source is the combustion of methane, but, under the 2200^{0} F front-end reaction furnace temperature conditions, carbon dioxide will react with hydrogen sulphide to give you small amounts of COS and possibly CS_2, and virtually every sour gas processing plant has CO_2 in its feed stall.

MR. W.A. FLOOK

So there is another source of carbon?

DR. J.B. HYNE

If you could feed pure H_2S into the front-end reaction furnace with pure oxygen, then you could remove completely the COS and CS_2 problem.

DR. W.R. TROST

Referring to the previous slide that you had on, in which you had indicated nitrogen, but no oxygen in the stack gas, is there in fact no oxygen in the stack gas as it leaves the stack?

DR. J.B. HYNE

There is a small amount. It's variable because of the necessity to maintain the proper ratio of hydrogen sulphide to sulphur dioxide for efficient Claus converter reaction. The stoichiometry that is required in that central section of the three converter beds is two to one H_2S to SO_2. This in turn is determined by adjusting the front-end reaction furnace ratio, where you feed in the oxygen and affect your burning some of the hydrogen sulphide all the way up to SO_2. That SO_2 then reacts with H_2S in the converter bed.

DR. W.R. TROST

And the object is for most efficiency, to use up as much oxygen as you can to get the least throughput, is that it?

DR. J.B. HYNE

Indeed, and one of the typical components of a well-run sulphur plant is-- believe it or not -- hydrogen in the tail gas, which is the very opposite of the oxygen. You are reducing conditions, rather than oxidizing conditions. Another reason for keeping the oxygen level at the minimum required for efficient operation is that it is a source of oxidation of SO_2 to SO_3 which then cause sulphation of the converter bed catalyst and diminution of the efficiency of that section of the plant.

DR. W.R. TROST

Do you feel that the absence of oxygen in the effluent may help to explain some of the smothery reactions that people have complained of when they were exposed to these downward plumes?

DR. J.B.HYNE

I would have to say that despite the fact there might be no oxygen in the stack, I doubt very much if what Mr. Gusella was breathing when he was hit by the plume was something that had no oxygen in it. I think with the diffusion behavior from the stack to even a mile down, that there is bound to be a lot of oxygen in there, even though there may have been none in the actual stack.

DR. W.R. TROST

There has been some reference to research done jointly among industry, and with academic input. Do you want to say a word or two to us about the Sulphur Research Institute?

DR. J.B. HYNE

From an organizational point of view or a research activity point of view?

DR. W.R. TROST

A little bit of both.

DR. J.B. HYNE

Alberta Sulphur Research Limited was incorporated under the Companies Act in Alberta in 1963, so it's almost ten years old. It is housed in the Chemistry Department at the University of Calgary by agreement of the Board of Governors of that institution on a three-year basis. There is an arrangement whereby all members of the group participate in the instructional activities of the Department of Chemistry, so they are indeed an essential part of the operation. The membership, when it began in 1963, was eight companies. It is now 26. Roughly speaking, the membership of A.S.R. represents better than 95 percent of sulphur production in the province of Alberta. The principal research activities of the group at the moment are three-fold, roughly 30 to 40 percent and 10 percent activity. Thirty percent of the effort is directed to the kinds of things I have been discussing here -- in plant problems, particularly the front-end reaction furnace, and tail gas cleanup. We have not concentrated our efforts on the Claus converter beds for a number of reasons -- not because they lack importance, but we like to share the tasks and the Chemical Engineering Department of the University of Alberta in particular has been very active in this area. The 10 percent is on what you might call trouble-shooting. In the past we have done a lot of work on down hole deposition of sulphur; in fact this was one of our major activities in the middle sixties, when everybody wanted to produce more sulphur for very obvious reasons. These emphases of course change. More recently we upped our efforts in something that is obviously, if indirectly, related to environmental quality control in regard to sulphur, and that is the exploration of new uses for elemental sulphur. If we are going to be producing eight to ten million tons a year, and only selling four or five, and if we want to keep the price of sulphur anywhere viable, we have to find new uses. This is a whole new area which may or may not be within your area of interest.

DR. W.R. TROST

Let's look at the tail gas cleanup situation first of all, with reference to the proposed guidelines from the Energy Resources Conservation Board. We've had figures indicating that to meet the proposal of guidelines, capital expenditures in the amount of $34 million might be needed in industry. We've also had figures that are very high, suggested as possible capital costs to meet presumably those same objectives. Would you speak on that point and see if you can clarify it for us?

DR. J.B. HYNE

What I would like to do is to put two numbers before you and then work with them; if people don't agree with the numbers, they can scale down the rest of what I have to say accordingly. But let us say that it's going to cost fifty million dollars to achieve the present regulations for the Province of Alberta. Let us say that on the other hand certain people have aspirations to 250 to 500 parts per million stack mouth values, which are not unknown. The former figure is touted as being the requirement in Florida for 1974, and 500 parts per million at the stack mouth is already law, to become effective on 1 July 1973 in the Los Angeles basin. Particularly on the second point, it should be noted that this is an urban area, the Los Angeles basin and the environmental air envelope there is already heavily loaded with all kinds of other anthropogenic effluents. However, having established these two figures, fifty million to cleanup to the present requirements, and looking at three to five hundred ppm -- let's say five hundred to play on the top side -- the present requirements see 99 per cent recovery for plants in excess of 1000 tons per day. The others are easier, so let's take the most stringent case. That's ten thousand parts per million when diluted, because that's the part of the sulphur you don't recover. Then you dilute it in the system, and up the stack. When diluted, that ten thousand parts per million will probably be around five thousand parts per million in the stack. So, with requirements the 99 percent for the big plants, you are probably looking at around four or five thousand ppm, including COS and CS_2, all sulphur volume. Now let's look at 500 ppm, that's a factor of ten, downwards in reduction. As we have indicated on costing, as you reduce the ppm in the stack the cost goes up, not linearly, but exponentially. Let's argue again in favor of minimizing costs. Let's assume that's a straight line, not a curve, heading up in the dollars. If it's a linear relationship -- and this is about the third favorable assumption we have made in this argument -- if you are going to go down from five thousand ppm to 500 ppm, that's a factor of ten, but the five thousand ppm is going to cost you fifty million dollars. On the assumption of a linear relationship, not an exponential, ten times fifty million dollars is five hundred million dollars. Will five hundred ppm represent no inconvenience? I doubt it very much. If we have a hearing like this ten years from now when we no longer have the half billion dollars, I suspect there will still be people on this platform saying that they have been inconvenienced. Society has to pay to remove hazards. There is no excuse for a hazard; but an inconvenience -- half a billion bucks would go a long way to do a lot of other things for society.

DR. W.R. TROST

When in fact the present guideline does not call for the five hundred parts per million?

DR. J.B. HYNE

No, it calls for 99 percent in the big plants, which as I indicated would be equivalent to about four or five thousand ppm at the stack mouth.

DR. W.R. TROST

So that the figure we have been given at 34 million to meet the present and projected guideline from the Energy Resources Conservation Board is not a bad estimate?

DR. J.B. HYNE

It's awfully difficult to be dogmatic in these things. It depends on who you are. If you are the contractor selling, you are obviously at the bottom end of the scale. If you are the operator buying you are at the top end of the scale.

DR. W.R. TROST

The point you were making, and making clearly, is that you pay increasingly for each additional increment of removal?

DR. J.B. HYNE

Yes, and the calculation that I did assumed linearity, which we know not to be the case. It's not nearly as good; its exponentially out.

DR. W.R. TROST

Do you want to comment a little bit on research and prospects for alternate uses for sulphur?

DR. J.B. HYNE

The two major areas of industry-supported research in the Calgary area, that I think may be of particular interest to the Authority, are the special work that has been going on now for about eighteen months in improvements in the front-end reaction for components for the three-stage sulphur process -- front-end reaction converters -- and tail gas cleanup. I don't know if Mr. Chalmers was alluding pleasantly to whatever benefit this work may have been to him, but one of the things that we have been particularly interested in is what minimal cost changes for maximum benefit can be made for presently installed front-end reaction furnaces to increase the conversion efficiency there. Obviously if you are now running at sixty, that means you are loading downstream units with 40 percent. If you can hike from 60 to 70, then that just means that you are loading the downstream units of the plant with a little less, so that they can work a little better.

The front-end reaction furnace on the left here is where we have been concentrating this effort. You have installed units there -- thirty feet long, twelve feet in diameter furnaces -- I don't know how much they cost, but they are worth several hundred thousand dollars; it's installed equipment and nobody's going to move it, unless he absolutely has to. The things we have been concentrating on are modifications of the fuel and air nozzle injection system, to achieve better homogeneity of mixing and to encourage more efficient reaction. An area that has been until recently almost an art rather than a science, is the internal components of that furnace -- things called checkered walls. They do two things primarily. They act as secondary mixing nozzles, with just perforated block walls. In addition they act as heat reflectors to homogenize the temperature within the reaction vessels, thus giving you a larger and more efficient reaction volume. We have been looking at the potential catalytic role of the internal components of the reaction furnace. This is normally called the thermal region, which presumably doesn't have any important catalytic role, but catalysts can be important there, particularly in the matter of the formation of sulphur trioxide, which of course is deleterious. If you can minimize the formation of SO_3 in the front-end reaction furnace you minimize downstream sulphation of the catalyst. We have been devising methods for measuring the temperature and sampling the gases from right inside the reaction furnace, so it is not a question of sampling the tail gas or the stack gas to find out what's going on in the system. You go right into the individual reactors so that you know precisely what is happening. I might add here that all the way down within the plant Mr. Lukacs was talking about telemetering information back from the field into the plant, and Mr. Chalmers was talking about his panic buttons that would shut down everything. I wouldn't like to be in the plant when that happened, but a large number of plants, particularly the larger ones in Alberta, over the last five or six years when instrumentation development has been very, very marked (six years ago there probably weren't a couple of plants in Alberta that had detailed in-line monitoring by gas chromatography and by temperature sensing within the plant)....I would guess that getting up to half the plants in Alberta now have very sophisticated tabs on every stage of the plant -- the inlet temperature of each converter, the exit temperature; some of them even have probes in the catalyst bed to find out if the catalyst bed is homogeneously operative. Tail gas of course is analyzed; they've got feedback systems. In fact there are commercially available feedback systems through analog computers now to control the front-end ratio. So these plants are really becoming exceedingly tight. Without naming names, you've heard in the last day and a half that you can get success if you push in this direction. That's all I would say in this particular part of A.S.R.'s research.

I would now like to go on to the new uses. One of the things that has to be recognized the moment you tackle the new use question is that while it might be very interesting to find a new use for a hundred thousand pounds of sulphur a year, which is a sizable amount of a chemical, a hundred thousand pounds a year isn't going to be noticed out of four million tons a year. So if you are looking for new uses you are looking for new uses that are going to move sulphur in quantities of a million tons a year, up. If you search the commodities market you very quickly realize that the only commodities that move in these quantities are almost exclusively the latest of the construction industry: steel, lumber, concrete, paving materials, road building materials, and so on. This has tended to rather crudely point the direction for new uses of sulphur if we are going to solve Alberta's overproduction problem. The industry itself has been very active in this area, and one of the major companies that operates in Alberta has been working on foam sulphur, a sort of styrofoam if you like, and another major company has been active in the area of road paving materials, the sulphur-bitumin composition. Our work at A.S.R. has been in the more classical areas of construction materials. It's not very sophisticated, but it involves a lot of outdoor work, testing of blocks, patio type blocks, panels, both for paving -- I don't mean road paving but sidewalk paving -- and for cladding the outside of homes. We use such materials generally available in Alberta and Western Canada as sawdust and straw; we've tended to concentrate mostly on organic type materials for chemical reasons.

That work is progressing; there is one very severe difficulty which Canadians had better face up to in new uses for building materials fabricated from sulphur. I do sincerely hope that Dr. Ortega at McGill removes his graduate student and his wife from the sulphur house before Montreal gets its first below zero weather, because the strength of sulphur goes through the most amazing gyrations as you go from 40^0 F to -40^0 F. We had a wall literally blow up on us last winter because of the stresses and strains that resulted in the building materials as a result of these huge thermal changes. This is a problem that I think can be overcome through additives, but it is a problem, and certainly will be a difficulty if sulphur is ever used as a construction material in the North, where it is an attractive possibility by virtue of the fact that the faster you cool sulphur the stronger the bond it makes with itself. This of course is one of the great difficulties with concrete construction in the Arctic --the mortar freezes before it sets. On the other side of the coin, what you might call the more sophisticated, further-down-the-road kind of research and new uses for sulphur, there is the whole business of building sulphur atoms very specifically into organic molecules, the sulphur-based polymers, developments along the lines of thiol, and so forth. We have plasticized sulphur, we have sulphur putties, we have sulphur glues, this kind of thing, but these obviously aren't going to move tonnages of sulphur. The results aren't going to come quickly, but it's conceivable that two or three years down the road the results could come that might move half a million or a million tons a year of sulphur in a construction kind of way.

DR. W.R. TROST

What prices would those kinds of products command?

DR. J.B. HYNE

The figure I am giving you is about a year old, but allowing for a 100 percent mark up to cover fabrication costs, marketing etc. an 8" x 16" x 3" patio block type thing, fabricated about 90 percent sulphur, 10 percent cheap organic additive, would retail for about 16¢ or 17¢. This was a year ago, as against at that time about 23¢ to 25¢ for the corresponding cinder block, so I am not suggesting it's vastly cheaper but I am suggesting it is comparatively cheap.

THE ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS IN ALBERTA

Calgary, Alberta
October 16 and 17, 1972

Submitted by: W. Gusella

To Whom This May Concern:

A memorandum written at the request of the Energy Resources Conservation Board an to be submitted to a Public Hearing at the Jubilee Auditorium on October 16, 1972 at Calgary.

To begin, may I state that I am a farmer, farming in partnership with my son; we farm a section of land broken up into two half-section farms, one-half (the home site) being located directly south about 2 1/2 miles from the Home Oil Plant which itself is located about 8 miles south west of Carstairs. The other half-section is located directly east of the "Gas Plant" and about 1 1/4 miles from it. The location of our land puts us in the position that when we have a north wind we are subjected to the "effluent" from the Home Oil Plant on the south farm (effluent meaning the gas discharged from their chimney), and when we are subjected to a west or south-west wind we are subjected to the effluent on the east farm.

When the Home Oil Plant was first built which would be about 14 years ago, they had a "comparatively" low incinerator stack and the first spring they were in operation I happened to be seeding on the farm directly east of their plant. I happened to be seeding in a direct air line just about straight east, and at varying distances from 1 mile to 1 1/2 miles. One day with a west wind blowing, I was subjected to the stack effluent right at ground level. The concentration of what must have been hot sulphur dioxide was so strong that I could not breathe any fresh air. I realized what was happening, shut down the tractor and started running at right angles to the prevailing wind stream. I was just "blacking out" when I broke into the fresh air and gradually regained normal breathing. After a while a wind shift or temperature change caused this "gas" to lift and I then continued with my seeding.

About a month after the breathing episode, we were subjected to about three days of drizzly weather with a light north wind. We were now subjected to this effluent on the "home farm". The farm buildings and all our feeding yards are completely surrounded by a windbreak of two to six rows of trees of varying heights. With the light north breeze prevailing, the "gas or effluent" appeared to hang or settle within this windbreak and my son's house, also located within this tree shelter, and which had been painted white sometime previous to this, now in the space or time of three days changed colour to a blotchy grey, white and dirty white and some patches almost a tinge of black. I thought it must be the sulphur dioxide in the air that was causing this paint change, so I immediately went to the Home Oil Plant and reported this. Mr. Howard Geddes, superintendent of the plant was away at the time, but a Mr. Brooks came out to the farm right away. He left without any comment and for several days we had different parties inspecting the paint on this house without anyone commenting. They even brought a Mr. Dinnigan (a paint expert for Bapco Paint Co.) from Calgary, and they also took paint scrapings and sent them to Edmonton for analysis. By this time Mr. Geddes had come back and he mentioned to me in a private conversation that the Gas Plant was at fault, and that sulphur had been absorbed by the paint from the effluent, but because we were the first ones to complain he was going to fight or contest this because he did not want this idea of damage claim to become prevalent amongst the surrounding farmers. Rather than contest this, I dropped the paint matter, but may I say that the following paint jobs on this house are not proving satisfactory, and to get a good job all the paint may have to be scraped off. At this time I also mentioned to Mr. Geddes the trouble I had at seeding time, so he then informed me that the original incinerator stack had proved itself too small and too low, and they were even then in the process of building a bigger and higher stack. When completed, this higher stack improved the air pollution under "general" air conditions, but when "atmospheric conditions" were just right we were still subject to this gas pollution on both farms.

Another form of gas pollution effect was noticed on our pine trees in our windbreak trees on our home site, as of the winter of 1971. It so happens that we have several rows of local spruce trees on the north side, several rows on the south and some interspersed in the windbreak protected site for ornamental effect. About a year ago I noticed that just about all the outside row of spruce trees on the north side were turning brown, and effect best described as "wind-burn" or "gas-burn". This browning effect was quite gradual and appeared where the north wind would hit the outside rows. This burning effect just showed on the outside row, and did not show on the inside rows or inside the windbreak site. A neighbor's trees about 1 1/2 miles south of our location also showed this same browning or burnt effect wherever his spruce trees showed clear above and through his other trees on the north side of his windbreak. I made a report of this browning or burned effect to our county weed inspector (a Mr. Snyder) and he said he would come out and inspect the trees, but he never came. This spring and summer I noticed that this "browning" had disappeared, and the trees appeared to be making a comeback.

Another bad effect of this sulphur-laden air pollution was its effect on all ferrous metals whether galvanized or not. This last few years all machinery made of iron, steel or cast iron showed an accelerated coating of coarse grained rust. All galvanized fence wire showed this rust, and it especially showed this rusting where the wire was stapled to the fence posts with iron staples, gradually "creeping" to either side of the staple.

Another instance of this rusting tendency was noticed on our women's clotheslines where they hang out their weekly wash. This got so bad on our own line that it had to be replaced with a new one. These lines were all stranded, galvanized wire.

A further rusting was noticed on the telephone lines. It just so happened that about two years ago our telephone lines were placed underground, and the old galvanized wire was rolled up, and it, with all telephone poles, were offered by auction to the local farmers. We ourselves bought several mile long rolls for farm use and to find clean galvanized wire we had to pick through the pile to find rust-free rolls.

It has also so happened that this last winter the Shell Oil Co. has built a "compressor station" on our neighbor's land directly due west of our home buildings and about 3/4 of a mile from same, and about 450 yards from the nearest point of one of our cow pastures. On the morning of the 14th of September, 1972, we noticed one of 22 bred heifers we had running in this pasture was "down" and appeared to be in serious trouble. My son immediately phoned for Dr. Sutmoller, the local vet, and within an hour he was at the farm. I went with him in his car right out to the young cow, and, upon examining her with a stethoscope he said this animal was in serious trouble, the symptoms showing raspy, harsh breathing and lung trouble. Since she was still alive Dr. Sutmoller said he would give her a sedative and some other medical injections. We then both made a visual inspection of some low spots in the pasture for poisonous weeds and also inspected the water supply in the dug-out for algae, scum, etc. We then returned to the cow and found she had just died; we had been gone only about ten minutes. An autopsy was performed by the Doctor and the only visible evidence of any injury or irritation was noticed in the lungs which were "filled" with a dark red blood. Dr. Sutmoller then sent the heart, lungs, liver, spleen and the brain to the provincial pathologist for analysis. All this happened on the morning of the 14th of September. My son then phoned the Energy Resources Conservation Board at Red Deer about probable gas pollution perhaps killing this animal, and next morning their man was right out here to make an insepction, but before he came to us he made a visit to Home Oil Plant north of us and to the compressor station west of us. He also visited several of the neighbors around us. We were informed that the compressor station west of us had had troubles on the night of the 12th of September, 1972, and the night of the 13th of September, 1972, and each time they had trouble they had vented raw gas from their compressors and a storage tank into the atmosphere. It so happened that I had inspected these 22 heifers on the evening of the 13th and my son had checked them on the morning of the 14th, which was the morning the heifer died. We are satisfied in our own minds that the vented gas must have drifted onto our pasture, seriously injuring her lungs and killing her, but the vet tells me that gas in the lungs is very hard to trace as it is absorbed and dissipated very quickly.

The afternoon of September 14th, 1972, I was also working on the east side of our farm east of the Gas Plant, and with a south-west wind, the atmospheric conditions were such that the sulphur dioxide from their stack was drifting at me right on the field. This had a stifling, nauseating and throat-burning effect with burning of the eyes and also caused a severe headache.

I have also been informed that this gas plant may vent or liberate just so much sulphur dioxide per month, but the weak point in this appears to be that they may vent concentrated volumes for one or two nights, then nothing or very little for several days and this way it keeps their average monthly emission well within their allowable limits. But it could be that these heavy concentrated emissions could be doing a lot of harm -- if the atmospheric conditions were just right at time of emission.

A matter of interest that I wish to record is that on a fishing trip to Lake Kananaskis this last summer, I noticed a "browning" or "gas-burn" of the pine trees on the west slope of the mountain range lying east of the road going to the lake. This is on a vast and extensive scale, and it makes me think that there has to be some gas well or gas plant that is venting some form of gas that is carried by the prevailing winds which impinge against these western slopes and cause this extensive damage to these western slopes. Certainly the trees show a lot of damage and they could well bear an investigation as to the cause of this browning or burn-effect.

A further matter of interest is that during the rainy weather during the summer whenever puddles formed on roadways we would notice a slight yellow substance around the outside perimeter of the puddles which very much looked like sulphur. Dr. Sutmoller informed me that this had been noticed before and samples had been sent to Edmonton for analysis and this substance had been found to be pollen. But in our observation this occurred during the summer and early fall when all bloom on trees, shrubs and flowers had passed the pollen stage of growth.

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

Do you have any estimate of how long galvanized wire lasts, in your opinion, in an area that is not near or affected by....

MR. W. GUSELLA

It does not break very quickly. It shows the rust but it still stays there for a long time. I have had wire in there for ten years and it shows a lot of rust; it still stays but it is not good and it does not look strong or healthy or good anymore. It has been there for ten to eleven years at least.

MR. W.A. FLOOK

I am interested in how the gas got from that stack to where you were on your farm.

MR. W. GUSELLA

Dr. Katz was talking about the trees or the plume; now this did not act like that. It comes straight out of the stack and flattens out. I heard about you talking about the ceiling. That happens occasionally. We are in sort of a valley; west of us it runs right through from Calgary right on to Sundre, and if it happens to be a foggy day the smog from Calgary comes down and there is a ceiling and the effluent will hit that ceiling and go along with it, but the time that it came down there you could actually see the heat waves and they just went down. I am a combustion engineer in some ways too because I studied combustion, and I realize they talk about 65 mph velocity of the gases emitted from the stack. They don't look like that when they come up there because whatever atmospheric conditions prevail at that time, that ceiling comes down in a straight line and goes right down and it does not diffuse or disperse.

MR. W.A. FLOOK

You were able to see it just by the shimmer, not by the color. That was one thing that I was interested in, and the other is this. You say the elevation of your farm is 3900 feet. How high is the gas plant?

MR. W. GUSELLA

It would be in the vicinity of about 3500, I would guess.

MR. W.A. FLOOK

Then there is just about a stack height between your location and that?

MR. W. GUSELLA

There is another point. When they built the big concrete stack they had the little concrete stack to begin with and when that was too small and didn't prove satisfactory they built quite a high concrete chimney, but that apparently corroded badly and about a year and one-half or two years ago they built what I presumed -- I did not go there -- to be a stainless steel non-corrosive metal chimney but it looked of a smaller diameter, and it was a compromise between the low one that they used to have and the high one. They built it at about half way, which now puts it at a lower level than the old one used to be.

MR. W.A. FLOOK

In other words a plume that moves comparatively horizontally within a very shallow dip could in fact hit the ground at your farm.

MR. W. GUSELLA

Yes. This is within a mile that this comes down, and the farm rises a little; it's just like a valley in between. I am in a rolling country.

MR. W.A. FLOOK

The point that I am trying to make is a horizontal movement of the plume which would have touched the ground at your farm doesn't actually have to be....

MR. W. GUSELLA

There was a little bit of a slope.

MR. W.A. FLOOK

That was the point I wanted to make, and thank you very much.

DR. W.R. TROST

Mr. Gusella, the events that you have described to us -- and I must say described very well -- have been intermittent over the years?

MR. W. GUSELLA

It is never continuous. These weather conditions and something else affects them. Perhaps there are controls at the plant, emission controls or something, and perhaps atmosphere, wind direction, everything affected a different way. It is never constant. It is always there.

DR. W.R. TROST

What are the conditions like in between these events?

MR. W. GUSELLA

Quite comfortable. It is all right. It is fresh air.

DR. W.R. TROST

Have you noticed any change in the last year or so as against earlier times?

MR. W. GUSELLA

You still get the smells. We go to our farm and go southward about two and a half miles and we are a half mile east of the plant. (They're west of us and we go south.) When we get within about three quarters of a mile, and often when there is a northwest wind blowing and we are driving the car, it hits us right there at low level. It hits us. When these men talk about the gas going up, it does very often, but it also very often hits a low level.

DR. W.R. TROST

Would you say that you are in the foothills country where you are?

MR. W. GUSELLA

I would class it as that. West of us 25 miles they are still farming.

DR. W.R. TROST

Your terrain is quite rolling?

MR. W. GUSELLA

Yes, quite rolling.

CALGARY PUBLIC HEARINGS

October 17, 1972

Submission presented by: Dr. C. Ekstrand

I'd like to deliver my submission this morning as a farmer of the Delacour area of Alberta, and a farmer who has been resident through family connections in that area since 1894. I personally have been in the farming operations for the last four years, as an independent operator. During this period of time I have lived close to a gas plant, and have had a heater located on my farm for a period of four years.

My initial point of residence is in Delacour, Alberta, however, four years ago I moved to the Conneridge District. When inquiring about a parcel of land I was concerned about the existence of a natural gas heating unit, and I was concerned for a number of reasons.

Firstly, I was concerned with pollution, and in particular I was concerned with the odours of pollution. Secondly, I was concerned about the emission of effluents into the atmosphere, and my concern was the concern of a farmer. I was anxious to inquire into the possible adverse effects that this operation might have on my crops and upon my livestock. In order to confirm suspicions I had concerning the possibility of the adversities of having this heater on my property, I inquired with the neighbors concerning problems that they have had with this particular unit, and without exception my experience is that most farmers were hardly aware of the existence of these heating units. I was informed and to my knowledge there are no adversities associated with the existence of this heating unit. I inquired further and asked about the positive aspects that might arise as a result of having this industry within our neighborhood, and I was favourably impressed with the comments that I had received from members of that community. They particularly approached upon such things as the maintenance of roads, appearance of the heating plant which had been kept neat and certainly, eye-worthy in terms of its appearance through the clearing of litter, etc. I was favourably impressed with the comments that I had received from neighbours in the community about the public relations that had been manifested by the plant at Balzac, and so, my fears and qualms squashed I proceeded to purchase the farm and since then have been virtually oblivious to the plant and its heating station. It hasn't affected me in any way, nor has it affected my neighbors.

One year ago, I proceeded to inquire about the purchase of another farm, and this farm happened to be two miles east of the Balzac plant, and again one of the reasons for purchasing this farm was that I thought it had development potential. In the middle of the land there was a ninety acre lake and I thought I could farm the area circumventing the lake and perhaps in the future, develop the body of water itself. I was obviously highly sensitive to any threats of odour and pollution, and if I am to realize the benefits from development, then I would have to be extremely concerned about the possibility of the emission of offensive odours.

Again I surveyed the neighbors in the area, inquiring about the possibilities of pollution, about odour pollution and highly dense effluent pollution. The responses that I received were negative. The farmers told me that they had experienced no adversities resulting from harmful odours, and again the weight of the comments was far more positive than the inklings of negative comments that had been raised. They spoke of the good maintenance of the roads in the area, and how when called upon, the plant, had been an effective working partner with the community.

As a person concerned with the well-being and welfare of Canadians, and those people within my community, I have been a hopefully informed citizen following the proceedings of this particular organization, and I wanted to confirm with myself the possibilities of adversities arising from the existence of this type of operation within my community. I thought that if I were to circulate a plebiscite amongst the neighbors to find out whether or not they were willing to commit themselves to a plebiscite, which either confirmed or opposed existence of this particular body, that I would have a better idea as to how people really felt about the existence of this particular type of establishment within the Municipality of Rocky View. In doing so I circulated a petition to the neighbors who circumvented this gas plant and who lived close to one of the heating units. I'll read the plebiscite I circulated: "We the undersigned either live closely proximate to the Petrogas Processing Plant at Balzac or to one of their pumping stations and would like to place on record that we have no reason to be concerned with the manner in which the plant operates. To our knowledge we have remained detrimentally unaffected by its existence and consider it to be a valued member of our community and economy". I took this petition around to twenty-three farmers and without exception, each farmer has signed the petition. I would like to pass a few comments on, as an individual who is both a farmer and who has another profession. Perhaps five or ten years ago the natural gas plants may have been at fault in emitting pollutants in to the air, but I think as of now that is past history.

I think we should take a look at the motivations of the farmers, people who are concerned about pollution and have been giving many of these criticisms. I think in some instances they have been selfishly motivated, and that the pursuit of the windfall gain, or the settlement against the company has to be viewed in strict objectivity. As a matter of fact, I find it rather humorous of a farmer to hear that it is always the fatted calf that has been detrimentally affected, or that it is always the prime heifer. As a farmer, thinking as a farmer, there is no group within our society who has displayed the attributes of poor mouthing than has the farmer. In times of plenty the farmer always has problems of storage and problems of marketing. In times of scarcity and in times of less profit, the farmer is prone to complain about the adversities of nature and the way it has affected his operation. This has almost become a characteristic of farmers and if we are criticizing the natural gas plants within our community, it's no more so than the way we criticize any given farmer within the same community. It's almost a way of life of farmers to vent their frustrations in the form of criticism. And I speak as a farmer.

Looking at a natural gas plant I think that we have to determine its worth as a relative concept and we have to adjudicate upon the existence of the plant in terms of its merits as well as its demerits.

When one takes a look at the economics of gas plants we find that generally speaking gas plants can be considered a high wage profession. Secondly, to my knowledge, I am not aware of gas plants not paying their taxes. In many cases, their taxes are higher than would be paid by the same landlord if he were to be a farmer. Thirdly, we have to take a look at the appearance of gas plants to see whether or not it is to the detriment of the community, and again gas plants from my experience have been well maintained, and certainly neat in their appearance.

If one wishes to make the routes of comparison, I think we should take a look at farming; farmers in the way they carry on their operations in the same community. Have you not seen farmers, with farms that you would like to see cleaned up? Farms, that have been littered, litter strewn, from one end of their fence line to the other. When we take a look at the matter of odour, again, as a farmer in the Conneridge Community, I am far more concerned about the cesspool at the piggery at Conneridge, than I am about the slight, from my experience, slight possibility of odour being emitted from the gas plant at Balzac, and again the none too pleasant odour that we experience from feedlots. Again, in terms of effluent pollution, the farmers themselves are probably the greatest culprits in this area.

How many farmers have you seen burning stubble in the spring and in the fall, and at the same time blackening our skies? How many farmers have you seen who constantly belch out diesel fumes from high horsepower machines? Again, I too am guilty of that, but the point I'm trying to make is that we are all guilty of pollution in a degree, and looking at environmental destruction, we have to take a look at the raping of the soil by poor farming practices of the farmers who are in essence burning out the productivity of their land. Farmers who do not properly control their weeds present as much a problem as any other business that I can think of, and that through their negligence they infest the total community with noxious weeds. I think the issue of environmental damage, certainly in my community, remains a mood issue. I remain unconvinced myself, and certainly those who I have contaced who live proximate to the gas plant; we remain unconvinced that environmentally we have been affected by the existence of this plant.

I think that in looking at the existence of a natural gas plant, one should take a look at it devoid of emotion, and vested interest, and I would imagine the best approach would be to cost-benefit the existence of this given industry.

All industries are open to criticism, whether it be the farming industry or whether it be the natural gas industry. In many cases, the price of progress is the price that we have to pay in order to maintain our high standards of living. However, I don't think that we should just look at the net private cost, and the net private benefits, but rather we should take a look at the existence of a gas plant, the existence of a farm from the point of view of the social benefits and the social costs that accrue as a result of the existence of that particular body.

In my submission, I would just like to make it known that as a private individual, having no vested interest and having no emotional barriers to the existence of a plant; that from my experience having lived close to a heating station and presently owning a farm that is two miles from a gas plant, I might add in the way of the prevailing winds, that I have experienced no adversities from the existence of that plant. I would like to put on record that I support the existence of the plant, not only from the point of view of it being a business enterprise, but as being a helpful and worthwhile and contributing member to the community of the Municipality of Rocky View.

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

First, how much of your time do you spend on the farm in the plume area of the plant?

DR. C. EKSTRAND

I live there full time. I do have a position with the Faculty of Economics and Medicine at the University of Calgary, but I live full time on the farm and devote five months of my summer to farming operations, as well as my evenings. For example, during harvest periods I do all the work on my farming operations, and I farm roughly sixteen hundred acres.

DR. S.B. SMITH

The other question is with respect to many of the complaints or statements made by farmers in several areas of the province which have received publicity prior to our hearings and which have been brought to our attention at the hearings. You mention the possibility of a windfall settlement, but do you think that all the citizens that have complained or made public their concerns have imagined or falsified their statements?

DR. C. EKSTRAND

That certainly wasn't the intent of my comment. From the point of view of my experience -- and I have lived in the Delacore area for the last thirty years, well for the complete duration of my life, and we are located on a natural gas field in that community -- we haven't been aware of any adversities arising out of the existence of this particular plant. The comment I was making was that farmers as a group quite often tend to poor-mouth their condition, whether it be one of affluence or poverty.

If people -- and this is true in any area of society I would imagine -- are aware of the possibility of gaining a windfall, in many cases they are prone to realize this opportunity. Now, it's quite possible that people could have been adversely affected by the existence of gas plants in other areas; I'm really not competent to comment upon what is happening in Pincher Creek, as a case in point. But from my personal experience over the period of particularly the last five years, I personally have not been affected adversely by the gas plant. My comment about a windfall is a derivative of comments I read in the paper concerning people who had dropped their petitions at some stage or other and, when they heard that a gain was to be realized by the farmers, took up their petitions anew. The point I wish to make is that what has happened five or ten years ago perhaps should be settled. Over the past five years, however, in talking to people who live in the acreages in the Springbank area and around Cochrane and have found that they too have not experienced the adversities that I have read about in the paper. I'm concerned that this type of vice might overwhelm a hearing of this nature, where only those people who believe they have been detrimentally affected, or are prone to mouth this type of criticism, are going to be the ones heard. I think as a private citizen I have the obligation and the responsibility to put forth my experience as one person having lived in the community. The comment about windfall gains wasn't intended to demean farmers who are concerned about the existence of gas plants, but rather to point out that motivations of this kind probably are evident and I think that one should weigh these with caution.

DR. S.B. SMITH

I take it from your answer then that you willingly concede that some people might have had difficulties?

DR. C. EKSTRAND

Oh, yes, quite definitely.

MR. W.A. FLOOK

Dr. Ekstrand,in addition to farming you are doing some land developing about a speculative piece of land?

DR. C. EKSTRAND

This is something that has happened over the past nine months, yes.

MR. W.A. FLOOK

You are referring to the Petrogas plant at Balzac?

DR. C. EKSTRAND

Yes, I am.

MR. W.A. FLOOK

Do you realize that the constraints under which this plant operates are the tightest in the province, and that their allowables for sulphur emissions are actually considerably tighter -- and they adhere to them -- than the ambient air quality standards?

DR. C. EKSTRAND

I wasn't aware of that.

MR. W.A. FLOOK

This is so, and it means that it is by no means a typical gas plant. Now you circulated a petition amongst the farmers which indicated in writing that they had no criticisms of the existence of the plant. This is indeed a very powerful weapon in your land development plans.

DR. C. EKSTRAND

I'm not really even concerned about that. I went into the land development nine months ago. I heard about these hearings about a week ago, and that certainly is in consideration. That type of motive I think should be heavily discounted.

MR. W.A. FLOOK

What I'm thinking is that you may be attempting to ascribe the desire for windfall gains to other members of the community, and suggesting that your own motivation might be to some extent in that direction as well.

DR. C. EKSTRAND

Let's view this in strict objectivity. First, the existence of a gas plant is readily apparent to those passing the road. In fact, it's a rather substantial edifice to the north of the road that they first arrive at, and I would imagine anybody who was contemplating purchasing a unit or an acreage in the area will have enquired into the possibility of offensive emissions from the plant; and second, it is a developed area. There are acreage developments in the area at the present moment, and they haven't been adversely affected. Had they been, I would imagine they wouldn't be there. My going into the land development area is certainly aside from the issue of my concern about public criticism of what I think to be a fairly innocent member of our community. I read about the hearings about ten days ago, and I was well on the way to development prior to that.

Institut
Français
du
Pétrole
North
American
Office

A PRESENTATION TO THE ENVIRONMENT CONSERVATION AUTHORITY OF THE PROVINCE OF ALBERTA

ON THE SUBJECT OF

THE ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS IN ALBERTA

BY

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PRESENT FOR I.F.P.

PIERRE BONNIFAY

AND

JOHN W. ANDREWS

Presented by: P. Bonnifay

CALGARY , OCTOBER 16,1972

CALGARY, Oct 16.1

Mr. Chairman
Member of the Authority
Ladies and Gentlemen,

PREAMBLE

The French Petroleum Institute, or as you shall hear several times in the next minute : IFP , is a non profit organisation engaged in Research work for Developping Processes used in Refinery, Petrochemistry as well as pollution control.

In being concerned with means of reducing SO_2 emission we shall be concerned also by cost. It is the purpose of this brief to considere cost of reducing SO_2 emission by using Claus Tail gas treating processes.

INTRODUCTION

We have assumed two situations and sulfur recovery levels:

- the first one following the guidelines proposed by the Energy conservation Board (information letter 71-29) which proposed for certain plants minimum recovery of the order of 98% to 99%.
- the second one following the regulation proposed by the EPA which call for all claus plants to recover 99.5% +
  Certain of the bried presented yesterday have established that Claus plant recovery consistendly in excess of 97% is beyond present technology of Claus plant design and operation.

Therefore goint to 99.5 or even 98% required additional processing of Claus gas effluent

To acheive these high recovery many processes are reported few of them however having operating experience:

i - For overall recovery Claus + tail gas treatment of from 98 to 99% such processes as

- sulfreen
- IFP-1 (basic process : referred to by Dr. Hyn) can be used.

ii- If recovery of over 99.5% is required , then such processes as

- Parson ,Beavon
- Wellman Lord
- Clean - air
- IFP-2

will be used

In this brief we want to estimate the economical impact (both capital investment and operating cost) of adopting the Conservation Board guide line or such recommandation as the one proposed by EPA. For sake of reliability of the data presented and consistancy of basis for estimation we based our study on processes we know best :

The IFP-1 for overall recovery from 98% to 99% wt

The IFP-2 for overall recovery in excess of 99.5%.

PROCESS DESCRIPTION

Without entering into technical details I want to briefly describe the two processing schemes which will help to comprehend the difference in investment :

THE IFP-1

In the first one the Claus reaction is conducted in liquid phase with recovery of the order of 90% (which could go as high as 95% depending upon the cases) on H_2S and SO_2 leaving the Claus plant. This gives overall recovery when used in series with a traditional claus plant of some 99% wt, a level which complies with the minimum sulfur recovery efficiency laid down by the energy resources conservation board.

The tail gas from the Claus plant is injected into the bottom of the IFP reactor while the catalyst solution is injected at the top, the reaction is carried out above the melting point of sulfur and molten sulfur accumulates in the bottom of the tower, where it is drawn off to storage. The catalyst solution is continuously recycled from the bottom to the top of the reactor. Cleaned gases leave the top of the tower and are burned in an incinerator.

THE IFP-2

The second process reduces sulfur compound emission form to much lower levels than possible with IFP-1.

As shown in Figure 2, the IFP-2 process uses two sections : an ammonia scrubbing section and a reaction section. Incinerated tail gas is scrubbed with a water solution of ammonia, and the cleaned gases are vented up the stack. The ammonia brine, containing sulfur salts, is evaporated and reduced to yield ammonia and sulfur dioxide. This stream is treated with hydrogen sulphide in an IFP reactor, as in the IFP-1 process, producing high purity sulfur, while the ammonia is taken off from the top of the tower and recycled to the scrubber.

The cleaned gas will have from 200 to 500 ppm SO_2 depending upon requirement. This correspond to overall recovery from 99.8% to over 99.9%. The later figure meets the most stringent regulation proposed by any county or municipal authority in the USA.

END PRODUCT

The end productof the two processes presented is sulfur of 99.9% purity or higher, bright yellow in color, containing minor mount of mineral and organic composition. There are no other products and in normal operation there is no discharge of pollutants. Therefore no penalty appears for wate disposal and no credit was given to the product.

ECONOMICS

The Tables which follows present typical investment and operating costs for IFP-1 and IFP-2 plants.

I want to define a little more what we mean by plant investment. The figures presented are battery limits and do not include provision for

- tie in
- instrumentation in the Claus
- contengencies for special requirements

nor does it include such items like

- chemical inventory
- interest during construction
- start-up expenditure
- escalation

Therefore the total project cost might very well exceed significantly the investment figure and there is no basic disagreement between a figure of 3MM$ as indicated yesteday which represent the project cost and the plant investment of 2MM$ which we show for the IFP-1.

CONCLUSIONS

It has been estimated by IFP that a gross plant investment expenditure of the order of magnitude of $20,000,000 is necessaru to have a small number of applicable plants within the Province of Alberta meet existing conservation Board guidelines, when the IFP-1 process is utilized to meet these guidelines. A plant investment of the order of magnitude of $140,000,000 is estimated to be needed to bring stack effluents of almost all the gas plants within the entire Province down to levels similar to those proposed by the US Environmental Protection Agency , when using the IFP-2 process to meet these lower limits. Using the project cost concept rather than the plant investment it is very likely that the figures estimated above would become respectively 30 MM$ and 210 $MM.

TABLE 1

TYPICAL ECONOMICS

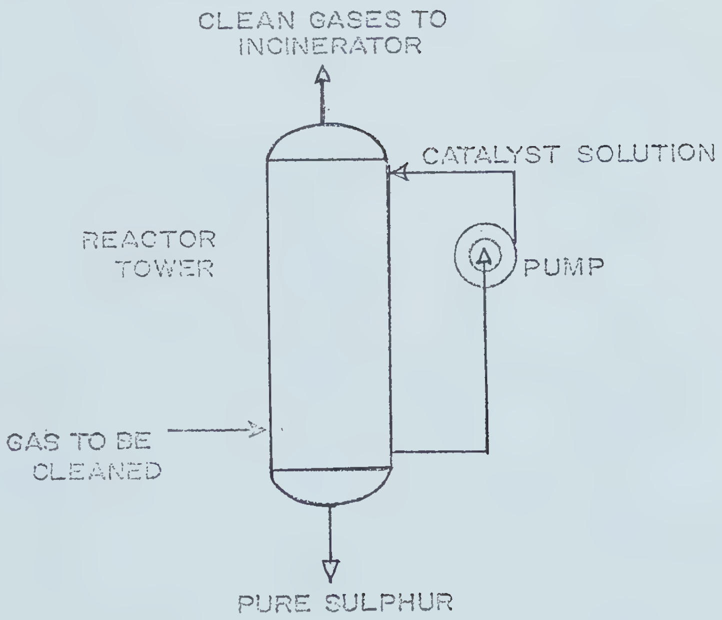
ALBERTA CLAUS PLANT	1400 LT/D SULFUR PRODUCTION 96.5 WT % RECOVERY 0.66 MOL % H2S + SO2 RECOVERY

	IFP -1		IFP-2	
OVERALL RECOVERY CLAUS + IFP)	98.0%		99.5%	
	(1)	(2)	(1)	(2)
INVESTMENT ($MILLION)	2.0	3.0	4.0	6.0
OPERATING COSTS ($/DAY)				
- VARIABLE CHARGES				
UTILITIES	30.		403.	
CATALYST + CHEMICALS	347.		4.	
LABOR	--		394.	
	(1)	(2)	(1)	(2)
- FIXED CHARGES TAKEN AT 20% OF INVESTMENT	1200 $/D	1800$/D	2400$/D	3600$/D
TOTAL OPERATING COSTS	1577	2177	3201	4401
CT/M STD CUFT §	1.1	1.5ct	2.2	3.1

(1) PLANT INVESTMENT CONCEPT
(2) PROFIT COST CONCEPT

§ REFERS TO TREATED GAS IN THE TAIL GAS CLEANING PROCESS

OWNER (AND AFFILIATE)	LOCATION	CLAUD PLANT	START-UP	% S RECOVERY IN IFP UNIT
NIPPON PETROLEUM REFINING (CALTEX)	NEGISHI, JAPAN	REFINERY, 3 STAGES, 300 T/DAY	SEPTEMBER 71	85
IDEMITSU OIL	HIMEGI, JAPAN	REFINERY 3 STAGES 250 T/DAY	APRIL 72	75
SHOWA OIL (SHELL)	KAWASAKI, JAPAN	REFINERY, 3 STAGES, 50 T/DAY	APRIL 72	85
CHEVRON STANDARD (CHEVRON RESEARCH)	NEVIS ALBERTA	GAS PLANT 3 STAGES, 250 T/DAY	JUNE 72	65
KYOKUTOH OIL (MOBIL)	CHIBA, JAPAN	REFINERY, 3 STAGES, 200 T/DAY	AUGUST 72	85
PHILLIPS	BORGER, TEXAS	REFINERY, 1 STAGE, 45 T/DAY	OCTOBER 72	92
MITSUBISHI OIL (GETTY)	MIZUSHIMA, JAPAN	REFINERY, 3 STAGES 200 T/DAY	END OF 72	85
MINISTRY OF GAS	OREMBURG, USSR	GAS PLANT, 3 STAGES 2400 T/DAY	END OF 73	75
		IFP - 2 PLANT		
UBE TOWN GAS	UBE, JAPAN	GAS PLANT, 12 T/DAY	OCTOBER 72	200 PPM SO_2 IN STACK GA



IFP-1 PROCESS

FIGURE 1

IFP - 2 PROCESS

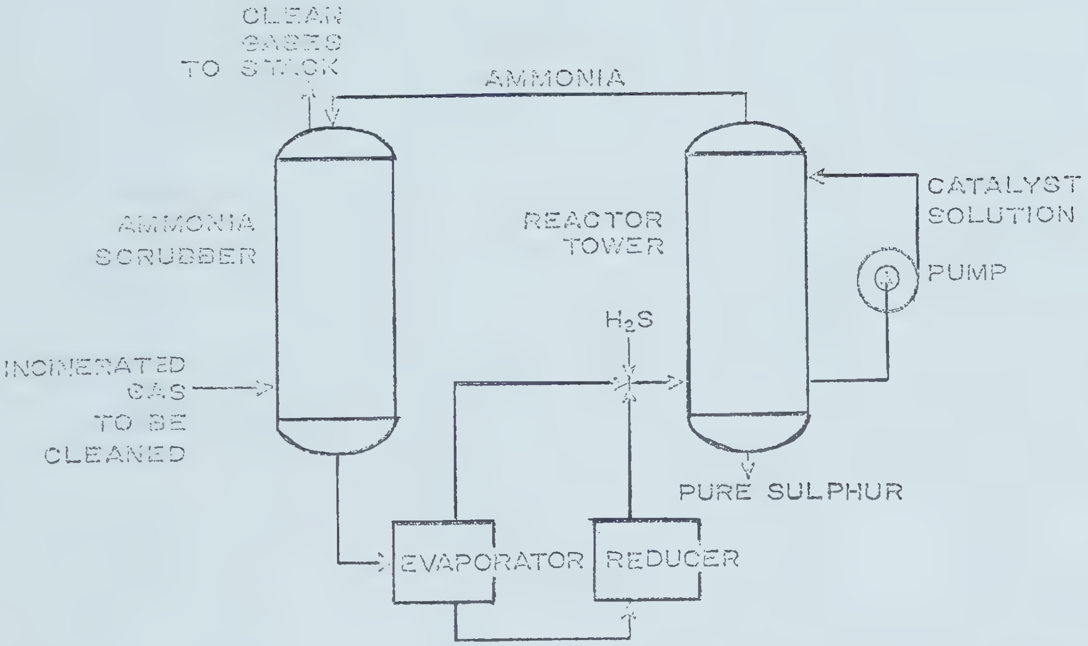


FIGURE 2

QUESTIONING BY THE AUTHORITY

DR. W.R. TROST

The major part of this submission has been made before, but you did produce some new material today, will you have a copy of that made available to us?

MR. P. BONNIFAY

I will send it to you.

DR. W.R. TROST

Thank you very much. I would like to just clarify two points while you are with us. First of all I.F.P. has actual plants in operation?

MR. P. BONNIFAY

Yes we do.

DR. W.R. TROST

The cost figures that you had shown us before--are they related to actual plant operation?

MR. P. BONNIFAY

Plant Cost.

DR. W.R. TROST

Now the other cost figures that you gave us, that 1.1 cent and 1.5 (I think it was for IFP1); did that include--I want to be clear on this--the capital costs?

MR. P. BONNIFAY

It does include capital cost, assuming ten per-cent amortization; and we have taken a very rough guess, a 20 per cent charge annually, so the lower figure which is 1.1 corresponds only to plant investment; and the higher figure in the bracket corresponds to the project cost.

DR. W.R. TROST

Thank you very much. And that appears in the additional material that you will provide for us?

MR. P. BONNIFAY

Yes

Submission presented by: Dr. R. H. Holmes
ERA Instruments Limited

I am President of ERA Instruments Limited. It is a Calgary company that undertakes services in the conducting of research in the environmental and resource sciences. A few days ago Mr. Baranuk of Amoco Canada announced that members of the Petroleum Industry who have gas plants located in the Whitecourt area of Alberta have commissioned ERA Instruments to undertake a rather detailed study of the environment of a corridor of northern forest that could possibly come under the influence of the gas plants in that area. The preliminary findings of this study were discussed briefly at the recent Whitecourt hearings. The governing body of this work has become known as the Whitecourt Environmental Study Group, and today in response to a request from this group, I should like to discuss with you what we consider to be some very familiar but basic concepts concerning the behavior of environment which we feel are very important considerations in developing a rational environmental management program.

The term environment is a word that simply means ambient or surrounding conditions. The conditions that exist at a particular location. The natural laws that exist in the universe are of course universal and those that are operative at any one place can be and are very complex. Each space or area has its own unique characteristics that are the result of natural laws that govern the behavior of all matter in that particular space. For example, the laws that are peculiar to natural selection in a particular region have produced the various biological forms that exist there. Further, the manner in which these natural laws have operated in these places have produced what we normally refer to as normal environments, and these phenomena are highly variable. They vary from day to day and they vary from season to season. In fact nature has never duplicated a single day, has never duplicated a single winter, or no other spring season has been exactly like any other previous spring, and while natural law per se is absolute and irrevocable.

The visible manifestations of natural laws vary with geographical location. In fact, this type of variability is the very essence of nature. May we consider for a moment what this means in terms of the environment in the Calgary or the Alberta area. Consider the temperature extremes to which vegetation in this area is subjected through a single cycle of seasons. Logically if the plants are not able to withstand this they would not survive. The vegetation that grows and flourishes here does so by virtue of the fact that it is able to withstand and indeed to depend on the extremes and the variations that occur in moisture and temperature, sunlight and in wind. The communities of poplar, spruce, willow, pine and juniper, all the animals, and the insects, are all indigenous to this region because they can either survive or depend on, or both, on the extremes and the variability in the environment to complete their life cycles. All these processes and phenomena are the result of the conformance of all living and inanimate forms to natural law, and this point, this concept applies to all nature, regardless of its position on the surface of the earth. It is important to understand that environmental extremes and environmental variability does not produce delicate balances in nature. Instead it produces zones or domains of stability. In some regions the environmental variability is very small, and so the domain of stability is restricted somewhat and may give the impression of the ecology being in balance. In actual fact the ecology is never in balance, and is in the state of continual change but always within its particular and sometimes very unique domain of stability.

At this point, or to this point, we have only talked about nature. Let's consider for a moment what man's influence might be on some zones of stability in our environment. Man can strip off the trees and he can plant crops instead. He can turn the land to agriculture, or he can harvest it for wood crops with the proposition of rejuvenation of the species to create additional harvest of wood later on, or he can make very deep incisions across the forest for a road or for a pipeline right of way. All of these things do intrude on the normal ecology and create yet other factors to be considered in delineating the zone of environmental stability. One then determines whether these intrusions can safely be absorbed within the natural domain or whether it in fact may create new zone boundaries that may be unacceptable.

For a moment let's examine the highly idealized diagram in *Figure No. 1. We have tried to illustrate this basic concept on this chart. It's not a very rigorous diagram, it will not stand up to careful scrutiny. We haven't yet decided how this should be presented. It is not as plain as I had hoped. The words written across the middle of the color blotch is domain of stability. Note that the two axes of this graph have upper and lower limits. The horizontal axis has a lower range, a little yellow spike and it refers to biological response. It also has an upper range at the upper spike corresponding to the outer limits of the domain of stability of the large color blotch. The vertical axis has an upper range and a lower range corresponding to the environmental variability that creates various biological responses. Hovering out in the middle of the grass somewhere, which we have simplified and diagramatically illustrated by increasing densities of color, is the domain of stability. This suggests that as long as the variability in the environment is within the limits that cause these various biological responses, the domain will remain relatively constant and the various biological entities will display a degree of resilience by moving around or by responding within this domain. The various responses may be negative and they may be positive. Note also that our illustration suggests that the area of most numorous biological responses is not near the edge; it is at these edges that the greatest uncertainly in survival of any particular entity occurs. We can carry our argument a little further perhaps to include the effects of man on the environment, and if the environment variability is not altered to the point of exceeding the limits that originally created the response limits in the biology, the domain will remain essentially unchanged and will absorb man's input. I want to talk about one set of reactions that contribute a great deal to this concept of environmental stability.

Figure No. 2. I'd like you to look at the arrows on this graph that correspond specifically to radiation reactions. On your left are reactions that refer to radiations that occurred during a daytime

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* "The figures referred to in this submission are available for viewing at the Information Center, Environment Conservation Authority, 9912 - 107 Street, Edmonton, Alberta.

situation, and on your right, that which may occur at night. The two steps of the graph were not made to correspond to a given day or a given night but are diagrammatic of a set of reactions that occurs at any location on the surface of the earth. Notice that in the daytime, the largest input is from the solar input. Some of the radiation and its constituents are absorbed or reflected by the atmosphere, but a large part of it does penetrate to the surface, and when it gets there it is further disposed of in a number of ways that is determined by the nature of the surface. You see a number of small, multicolored arrows at the bottom where the large solar input is divided into evaporation, radiation, and convection. There is long wave of outgoing radiation and so forth. The energy you see then at the surface of the earth is used by the surface to accomplish its various functions. Whether they be animate or inanimate. The night-time situation has the predominant reactions; the back radiation from the sky, which has an enormous input into the night-time radiation processes, and also the back radiation from the surface back into space. If it were not for the fact that the sun comes up the following morning, the surface of the earth would in fact cool to absolute zero. I don't know how long that would take, but this would give you some idea of the magnitude of the back radiation process. All of these processes have more to do with the surface of the earth and life on it; its nature, its characteristics, and the domain of stability of the environment at a particular place, than all of the other reactions in nature combined.

Figure No. 3. To further illustrate some of the complexity that occurs, these observations were taken with an instrumented airplane that was flown at very low levels and also at intermediate levels over an area of normal agriculture in the Brooks area of Alberta. Here one encounters irrigation, prairie lakes and also rather warm, dry land farming. You can see that the grey illustrates those areas that are cool; rather stable air which derives its characteristics from a cool surface. You can also see rather hot air which derives its characteristics from a hot surface. Consider now what could happen if a parcel of air were moving from your left to the right and encountered these different surfaces. The different characteristics that this air would have imparted from the surface as it moves from left to right. Consider then what would happen to a plume if it were injected into this airstream at a position just to the left of the graph. It would first encounter very strong convection activities, then it would encounter stable conditions. It would encounter other little parcels of stable conditions, an irrigated area, and finally back into hot heated air once more where the air derives that heat from the surface. This would cause a very distinctive plume characteristic.

Figure No. 4. This is looking down on the scene from a very high altitude. We can see the areas which are pink, are heated above ambient conditions, and those which are grey are the ones which are cooled. We would have to pay particular attention, knowing that this situation existed, and if we assumed that it was typical, our conditions during a July or an August day would have a great deal to do with the position of a plant and the possible effects in the surrounding environment of that plant and the plume coming from that plant.

Figure No. 5. This is a view of agricultural land and a sweep of foothills from the grandeur of the Rocky Mountains up to the complex atmosphere above. We tend to think that this sort of thing is very stable, and in fact, it is. However, the agricultural part of this domain must be renewed and preserved and must be maintained artificially by man in order to maintain its stability. If this were not the case, it would soon revert back to the characteristic of the original domain and become in time very similar to what it was before man arrived here. These entities in this biology are stable, and one examines this domain of stability to determine the margins that exist there and the degree of intrusion that this could stand. Keep in mind now, we are talking about Alberta conditions where environmental extremes are very great.

Figure No. 6. This is an area of muskeg in the Whitecourt district. A rather particular and peculiar setup of hydrologic conditions produces muskeg and the balance that produces muskeg and the domain of stability that maintains muskeg is dependent upon a very unusual set of hydrologic conditions. If this is upset, the domain changes and the boundaries of the domain change. One is tempted to contemplate the effect of rights of way roads, and so forth that may have an effect on the transfer of the near surface water, that at this time maintains the boundaries of this particular environmental domain.

Figure No. 7. This is a stand of spruce and pine, which is characteristic of many environmental domains in Alberta. This will take in a rather low level, and you can see here that the populations of spruce and pine are distributed so that spruce occupies about 60% of the vegetation, pine about 40%, and a minor amount of other species are there. This is a very stable area and this kind of biome is able to stand enormous extremes and variations in the environment. It takes a very strong intrusion into it to change the boundaries of the domain significantly so that we recognize any degradation of that domain.

Figure No. 8. This is an older stand, here in Calgary, and it is characterized by dozens of kinds of extremes. This is a natural hillside. It has not been cultivated, and has been grazed only by domestic animals. It has on it a community, a large community of Salix gauca, which is a willow tree that maintains its position, or maintains its appearance by dying back from the crown. When it dies from the crown the dead branches exist within the community giving the individual clumps of trees a very straggled appearance. This is the normal growth habit and appearance of this plant.

Figure No. 9. This is a close-up to indicate the degree, the type of domain in which this plant is. It is very hardy and is able to withstand enormous extremes, attacks by insects, temperature, and also by domestic and wild animals.

Figure No. 10. This is a hillside which was almost entirely defoliated, by attack of a particular insect whose population rises and falls in response to the variations that occur in nature that contribute to the populations of insects. Sometimes they seem to prey upon themselves and there is direct evidence to suggest that they die within their pollution because of the high numbers of a particular group of animals or insects. This particular one is a leaf curling insect which can defoliate an entire hillside and entire regions of a Province.

Figure No. 11. This gives a close-up of this particular animal in its early stages of infection. Eventually all the leaves disappear and look like the ones you can see which are curled up to provide a microhabitat for the insect itself as it lives through that part of its cycle. Now if this community of trees were to sustain this attack for three successive years, the community of trees would not survive.

Figure No. 12. The next figure is another insect. This one is not nearly as devastating but is one of the insect inputs into our domain and still has its large effect. It is peculiar to poplar trees and is a leaf miner that simply mines out the juicy succulent cells within the upper and lower epidermis of the leaf.

Figure No. 13. This is taken from the same hillside, but around the corner of a hump which has a different type of exposure and a different radiation balance. This turned out to be unsuitable for the insect and so this community of trees remains relatively undisturbed by all kinds of insect attacks. This group of trees can absorb an enormous amount of input and at this particular time it was absorbing the effect of domestic animals and was still persisting.

Figure No. 14. Wild animals wiped out the entire community of large poplar trees in this community to build a very small dam in a small creek. This is another kind of input into the natural, normal environment that contributes to the boundaries. It is a biological response to environmental variability that creates the boundaries of a stable domain within the environment.

Figure No. 15. This is a hedgerow of trees in the Turner Valley area which is undergoing very mild sulphur dioxide stress. This is the first time this hedgerow of trees has been examined for this particular problem. The source of sulphur dioxide that probably contributes to this stress has been there for many years and this community or group of hedgerow trees has very likely been subjected to this kind of stress for many years. Yet each year the trees send forth new growth, put forth new leaves, and increase in size as is the habit of growth of all trees within their normal environments. This particular domain has been absorbing sulphur dioxide into itself without changing the domains of the boundary because the vegetation still persists, and in fact looks enormously less stressed than the similar clump of trees not many miles away that was attacked by insects.

Figure No. 16. This is another small balsam poplar which has sustained damage by sulphur dioxide and also by sulphur dust. This particular stress is common to any kind of a tree that grows at the base of a sulphur pile, and there are many trees and many plants and grasses that do grow like this in these positions. At the same time this tree, I've watched these trees for a number of years, will continue to elongate about eight inches every year which is normal for growth of trees and the leaves. Parts of the leaves which are unaffected, this particular one is rather strongly affected by sulphur dust, the parts of the leaves that are incomplete and uncorroded do in fact continue to metabolize and photosynthesize and perform their function as leaves, not as vigorously as they would if they were unaffected completely, but they do carry on and the plant continues to grow. This domain of stability is in fact absorbing this input without appreciably changing the boundaries of the stability domain.

Figure No. 17. This is a sulphur dioxide stress plant which is wolf willow, also indigenous to this area. This plant and this community of plants and many others like it were examined a number of times during the season. It was found that this particular stress did in fact come and go. It was transient, and if the stresses imposed on the plant are less than toxic levels, the vegetation will rebound, will recover and will continue to grow as indicated here.

I would like to talk about sulphur dioxide and other environmental stresses, and indicate in perspective what it really takes to stress a tree so that you can visually see that it has been stressed by sulphur dioxide or any other environmental effluent. Most literature contains information and diagrams and pictures of trees, leaves and tissues that have been stressed under artificial conditions, where it is possible to control exposure levels and duration. In the noarmal environment it is not possible to do this and in fact you usually discover the stress after the fact, when it is not possible to measure the duration or the levels of concentration of effluents that were there. I am going to show you in the next figures, some stress trees where the levels and endurance of stress is known and also where it is not known. You must remember that a plant growing under controlled conditions does not exhibit the same type of stress symptoms as a similar plant similarly stressed in the normal environment. You can induce nitrogen, potassium or phosphorous efficiencies or toxicities in the greenhouse and get normal symptoms of this stress. If you place the same plant in the field and try and induce this, the symptoms of the stress can be entirely different from those that are induced in the greenhouse, in the laboratory or under controlled conditions.

Figure No. 18. The first figure than is a leaf, sprig, and branch of Populous tremuloides, the trembling poplar, which has been stressed by rather high concentrations of sulphur dioxide. This was taken from the natural environment where we artificially imposed sulphur dioxide into it. This is rather unusual in that it demonstrates the classical symptoms that one observes in a controlled environment for sulphur dioxide at high levels. You will notice that the necrosis is mainly restricted to the intercostal areas of the leaves, those areas which are in between the ribs and the veins of the leaves. Sulphur dioxide if it is not assimilated by the tissues of the plant corrodes those tissues and causes them to degrade and eventually die, but the remaining part of the leaf continues to photosynthesize. The plant, you must understand is reduced in vigour as a result of this influence but still continues to grow, and so long as the buds have not been imposed on, this tree will rebound the following year and grow normally.

Figure No. 19. This is another leaf of Populous tremuloides in the fields, which was under stress, three and a half months previous to this picture. This is rather typical of sulphur dioxide in the field under high concentrations. You will notice that it is not exactly the same coloration but patterns of stress are not the same as they were in the previous photograph. At this point may I emphasize that diagnosis of this kind must be made with extreme caution. Because of the great variability that exists in nature, an understanding of the controlled environment stress symptoms and an understanding of the environment is necessary to separate insects and nutritional disorders from those visual symptoms that one would anticipate from an industrial effluent. They can mimic each other to perfection.

Figure No. 20. This is a small tree of trembling poplar, also similarly affected but this tree is regrowing and the trees that were affected dur to toxic concentrations are not rejuvenating. That leaf is not regrowing; it is not replacing the dead tissue, but the tissue that was not affected is continuing to support the tree. We are talking about toxic levels and we continue to use the word toxic, and another word chronic, which is levels of stress which are somewhat less than those which cause death of the tissue or the organism.

Figure No. 21. This is buck brush held against the observer to show that the sulphur dioxide stress that was imposed very early in the spring on this plant completely killed the stem and the branch down to the apical stem where the growth began. When the stress was removed the new buds, because it was sufficiently early in the season, sent forth new growth and the trees completely recovered, even though the brown residue of the previously burned leaves was still there. The green and the figure of the plant was completely restored. Keep in mind we are talking about stability. We are talking about the environment's capability of absorbing and of incorporating external stress, and the natural variability that has resulted in particular environments already has a very wide margin of capability built within it.

Figure No. 22. This is ground juniper growing against a rock which appeared to be under very heavy stress and was. Later on in the season the greenery began to grow, and the following season, although that season hasn't arrived yet, we suspect that the plant will rejuvenate and regrow. These plants have been subject to levels of sulphur dioxide that were sufficient to induce stress symptoms that we can see, and see readily and characterize.

Figure No. 23. This is again Populous tremuloides, I keep using this plant because such large populations of this plant exist in Alberta from the far north to the south. This tree has undergone chronic sulphur dioxide stress and is recovering. It was examined a number of times during the season and this is the type of sulphur dioxide damage from which a tree normally will respond and recover. The leaves are not dead, they are stressed and discolored, but this is just about the upper limit of chronic stress that the plant could endure, and still recover. Most of the influences that we have seen are transient and do, in fact, when the stress is removed, show remarkable ability to recover.

Figure No. 24. Again to indicate proper perspective I'd like to show you this trembling poplar example, even though it is somewhat exposed. On your left is an end of a branch of a healthy tree, and on your right is a part of a tree that is under a nutritional disorder. The tree displayed strong symptoms of lack of vigour, had insects in the bark and had the result of nutritional disorders that come from this stressing. So we have mutual stressing, all symbiotically affecting one another. This kind of deficiency is very common in our natural environment, and it comprises again only a part of the biological response to external stress, which in turn contributes to the characteristics of the particular domain within which all vegetation resides. Similarly, insects and animal stresses are part of the ecological system. All of these contribute to the nature of the particular domain of stability and create the establishing of the extremities of the domain. Now, if sulphur dioxide or other effluents are injected into a relatively sulphur dioxide free environment it will be incorporated within this indigenous biological system and will create its particular response pattern. High levels of sulphur dioxide will impart a new character possibly to the domain and alter the boundaries to an extent that might be unacceptable. If the dosage however, of sulphur dioxide or other stresses is low, no effects on the existing domain will be noted. I should like to submit that the intrusions of sulphur dioxide into our Alberta environment, that we have noted to date, have imposed no serious constraints upon the domains of stability or on the vigour of the various equal systems which we have studied.

QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

You have dealt in Whitecourt and here at a considerable length with what you call the domain of stability, and you have compared a wide variety of observable resistances to climatological or biophysical natural circumstances with the resistance to stress that might be imposed on plant communities by SO_2.

DR. R. HOLMES

Well, industry generally.

DR. S.B. SMITH

Yes, Now, in my ipinion as a biologist you are on extremely dangerous ground in comparing unnatural or manmade chemical intrusion into a natural environment with climatological resistance for ant species of plant and animal. Would you care to comment?

DR. R. HOLMES

Yes, I would like to. I have developed the concept--this is not a new concept, incidentially; this is a fairly old idea, it's been coined recently to make it fit better with present concepts of environmental variability and biological reponse to it--I have developed this presentation today to show mainly what the environmental parameters are that develop this kind of response within the environment, unperturbed or unaffected by outside effects. It has just been the last few years that we have begun to be at all concerned about possible industrial input into the environment. It has been occurring a long time. We've just now begun getting excited about it, and since we're developing a rational approach to environmental work, we're postulating what the imput of industrial effects might be into a stable domain, a stable area of ecology.

I am proposing that in view of the fact some gas plants have been in particular areas for a fair number of years--ten years in some cases, maybe longer--we have looked at the ecology that exists in these places and based upon the observations this year, the observations that were made last year, and the observations that were made this year in surrounding and effected areas, have concluded that the input because of industrial stress into the domain of stability can be consdered on the same basis as natural stress.

DR. S.B. SMITH

Perhaps you misunderstood my criticism. Let me make another statement and have you comment on it. What I'm saying is that because an ecosystem shows naturally wide variability and strong resistance to natural environmental stresses there is no reason to suspect that it will show equal resistance to unnatural or manmade chemicals. Do you agree with that?

DR. R. HOLMES

Yes. I think we have to be very careful about this equality. I made no pretense to establishing equal absorptivity of industrial stress compared to natural stress. I'm simply indicating that the domain of stability has been created by variability and by stress and that we have to be very careful about the balance concept. We have to be bery careful about judging the response to industry of the natural environment.

DR. S.B. SMITH

Would you agree then that it would be fair to say that some species of plants which are resistant to the widest known physical chemical stresses may be the most susceptible to unnatural or manmade chemical stresses?

DR. R. HOLMES

That's a distinct possibility.

DR. S.B. SMITH

Such as lichens?

DR. R. HOLMES

That's right.

DR. S.B. SMITH

I wanted to make it clear because it may have been an accident in the presentation, but I gained the distinct impression that you were comparing. . . .

DR. R. HOLMES

I've got a paragraph here. I was goint to read. It makes that point.

DR. S.B. SMITH

Another point you make very clearly in regard to the processes involved with primary productivity in the biological systems, particularly in the plant communities where the promary productivity takes place of course, is that the insulation energy and the various changers in that energy through radiative processes and convection processes were perhaps more important than all others combines. I wonder if I could suggest that this is a little over-simplified; that the whole ecosystem concept as I have understood it for many years is concerned with understanding that all the processes, some of which are very minute, may be as important as this very large energy process which pours energy into the system. It seems to me you said that these radiative processes, the ones you illustrated with the slide are more important, or as equal to all others combined.

DR. R. HOLMES

No, I said they have more to do with making up the result and nature of the surface than all other processes combined. I think that argument still holds. I think that the radiation determines the photosynthetic process; it determines the nature of microhabitats for disease and for insects; it determines the rate of dew formation; it determines the rate of heat exchange, and the radiation balance on a surface is the critical factor in determining the nature of the surface. It is because of its radiation balance that it is as it is.

DR. S.B. SMITH

Well, we could argue. I won't go on there. I would like to suggest that the micronitches or climates have evolved in response to the radiation rather than radiation determining this.

DR. R. HOLMES

We're talking about the chicken or the egg now. I think the interplay between the various forces result in a radiation balance regime.

DR. S.B. SMITH

I don't want to indulge in an exercise in semantics or be argumentative, but I wnated it to be clear in my own mind what your argument was, and I wasn't clear obviously.

DR. R. HOLMES

Is there a question now?

DR. S.B. SMITH

Yes. You showed one picture of a muskeg and onother of a climax spruce pine forest, mixed forest and what looked to me like a climax willow association, some kind of calyx, I'm not sure what they were. Would you comment on the fact that a muskeg really is only the final phase in the evolution of what once was a lake or a swamp, I think you suggested that it was a very stable situation; I'm suggesting it's progressing to something that's going to be quite different, like a black spruce forest perhaps in another two hundred years. Muskeg isn't going to stay a muskeg forever.

DR. R. HOLMES

Absolutely not. Examination of various muskeg pieces indicate those that have been more or less stable than others. And a muskeg patch is a lake that gave up and simply is being covered overy by vegetation that's simply taking over that regime. And it is probably up North the more transient of all the domains that exist up there, because of this very sensitive hydrology that creates or destroys a muskeg situation. But in terms of our conditions--the amount of time that we have to industrially impose or artificially impose on an area like this--it is relatively stable. If we were to take a piece of muskeg that Samuel Hearn looked at and examined it now, there may not be very much change, but in the geologic sense it is undergoing constant change.

DR. S.B. SMITH

Finally, I'd like to ask you whether you have any body of data over any considerable time which will allow you to estimate, or compare statistically at least, the replications of sampling on known, (if possible) non-stressed areas and areas within plume influence so as to make estimates of the future production of wood in the mised forests--spruce, pine, or aspen or poplar, whichever--because they are all important in terms of the forest economy. I would like to know whether you have data which will allow you to make statistical comparisons in, as they say, known non-stress areas, if there are any.

DR. R. HOLMES

I discussed this very thing with a group of colleagues last year; we played this little game with ourselves and tried to design an experiment that might in favt substatiate this. We agreed that there was no body of data that would support this view. There is no collection of information on this topic but the instrumentation and the technology does now exist in order to do this. The answer to your question is 'no, there are no data that I know of that would do this', and 'yes, the talent and the instruamentation now exists in order to maintain this information'.

DR. S.B. SMITH

Would you think that a reasonable attack on a problem if these data are going to be published and if they have credibility for us, would be to deliberately use upwind data and compare with downwind data on a wide replication basis? Is that what you. . . .

DR. R. HOLMES

I would love to get hold of a think like this; I'd live to do it.

MR. W.A. FLOOK

Would you say that when there are instances of visible stress on the vegetation that Alberta air quality stantards here in fact been exceeded?

DR. R. HOLMES

I cannot make that statement. I don't know. This is after the fact. It's distressing that you arrive after the vegetations shows the symptoms.

MR. W.A. FLOOK

You wouldn't care to comment that the fact that the stress occurred means that the . . . .

DR. R. HOLMES

The only way I can go back to it at all quantitatively is to go back to the controlled environment work that I did a long time ago. I'll tell you about one experiment, very short. We had taken tomatoes which, are very susceptible to all kinds of stress, and we had exposed them in the greenhouse and got the classical display of the stress symptoms of flouride oxides, ozone and SO_2. We had duplicate sets; one set was in the greenhouse andone set on the golf course. We buried flush in the ground, let them sit there for three weeks to come to equilibrium, and then stressed then, we thought with similar levels. Every one of them died as a result of that stress, which was almost identical in the greenhouse.

MR. W.A. FLOOK

What I'm trying to dind out is, if you observed these conditions is it reasonable to assume that the protective air quality standards that have been laid down have been violated?

DR. R. HOLMES

The present air quality standard that I worked under for most of the time is 0.3 part per million for a certain length of time, and you can expose a tree for a half a day under 0.3 and it will display the symptoms. But the showing of the symptoms taken a few hours after the imposition of dosage, and the withdrawal of that symptom takes about four days after the imposition of dosage, and the withdrawal of that_symtom takes about four days after you shut off the dosage; and the plant provided you haven't established necrosis, is established back into its normal growth habits again, and will display no distress symptoms.

Submission presented by: Mrs. E. Tennant

Maybe it is appropriate that I talk after Dr. Holmes. He has a very illustrious background, and I couldn't help but think of what I heard at the IUCN meeting at Banff, and Dr. Craig said that, "Knowledge is one thing, but wisdom is another". I have almost been pushed to the limit. Don't use your knowledge to manipulate human resources because life is very fragile; life can be extinguished. Life is also persistent and he is part of the evolutionary process that has been going on for billions of years. You cannot put yourself in the place of the force that is behind this evolutionary process.

THE ENVIRONMENTAL EFFECTS OF THE OPERATION OF SULPHUR EXTRACTION GAS PLANTS IN ALBERTA

Submission Submitted by: PETROFINA CANADA LTD.
Presented by: MR. E. WICHERT

It is the purpose of this Brief to present some of the positive and beneficial aspects related to the operation of Gas Plants in this Province, in particular a plant located within 35 miles of the City of Calgary. We wish also to endorse and support the Canadian Petroleum Association Submission which deals in more detail with the technical and regulatory aspects of the matter.

Petrofina Canada Ltd. is the Operator of the Wildcat Hills Gas Plant complex and gas field located approximately 10 miles west of Cochrane, Alberta. The field contains sixteen gas wells in an area about 10 miles long and 3 miles wide to the north west of the plant. The Owner Companies are Shell Canada Limited, Imperial Oil Limited, Gulf Oil Canada Limited, Hudson's Bay Oil and Gas Company Limited and Petrofina Canada Ltd.

The plant was constructed in 1961 and went on stream in January of 1962 with the necessary approvals from all the Governmental Authorities, in particular with respect to volumes of gas to be processed, mechanical safety, emissions and product recoveries. The original plant cost was $4,773,000 to which has been added $1,942,000 making a total plant capital investment of $6,715,000. Of the $1,942,000 added capital investment, approximately $1,100,000 was recently spent on compressor facilities to sustain plant throughput, and of the balance of $842,000, $753,000 has been spent on improvements to the sulphur plant performance, stack modifications, sulphur handling, emission monitoring, water treatment systems etc., all related either directly or indirectly to emission control.

The drilling and completion costs in the field are $7,794,000 to date along with well equipment costs of $524,000. The gathering system costs are $2,235,000 to date. In summary, the total material investment in this complex, excluding land and exploration is $17,268,000. The royalties paid to date are in the order of $4,500,000, in addition to which all Federal and Municipal taxes have been paid.

There are thirty-nine employees at this plant, of which fifteen have been there since the first year of plant operation. It is apparent from this that our employees generally consider this to be a good and safe place to work. We submit that the operation of this complex has been most beneficial to the people of Alberta providing revenue, employment and use of many contract services since its inception and promises to continue this contribution to the economy in the future.

With respect to the measurement of sulphurous emissions in the area, over twenty field stations have been in continuous operation since immediately prior to the start of the plant. A graph of these monitoring stations when averaged shows that the sulphation in the area peaked in 1963 and 1964, and has dropped to about half this level in recent years. At the same time, the volume of gas processed in this plant has more than doubled. Only 0.020% of the time is the presence of any SO_2 detected by a sensitive continuous monitoring station located in the area. This steady improvement in the gas plant operation was initiated by the Owner Companies in 1967, many years before the current wave of concern about emissions. For the record, the actual total SO_2 emissions since plant start-up have only been 60.6% of the quantity permitted by the Government authorities.

This Company has always attempted to exist in harmony with the Community and believes that by past action, the general quality of the environment has not suffered damage due to sulphur emissions. For example, we have long since recognized that our plant is in a beautiful location along the Bow River Valley. We constructed ten years ago a picnic and barbeque area within 1500 feet of the sulphur plant and plant stack. This pleasant site has been used for staff barbeques by ourselves and other Companies, Community Clubs, School Organizations and Church Groups to such a degree that these organizations must book well in advance to avoid overlaps. Many of these groups come from Calgary to picnic inside a gas plant. We continuously take numbers of school children and other visitors through the plant on tours, and most recently have had college students who are studying the environmental sciences, investigate environmental affects in the area with our complete co-operation and help where requested. This would hardly be the attitude of a Company who felt it was committing environmental damage. It is worth remembering that this plant has operated over ten years, therefore, the long term effects should be known by now. Of further interest in the area is the value of lands. The cost of the first land we acquired for the plant site was one tenth of the cost of the next parcel immediately adjacent to the plant acquired recently for plant expansion. If gas plant operations damage the surrounding areas this escalation would not have happened.

That gas plants have operational upsets which create undesirable emissions for short periods at higher than normal rates is not denied, but these are rare and receive immediate corrective action. No one wants to correct these more quickly than we do as these upsets inevitably mean loss of production. After ten years operation at Wildcat Hills, we sincerely believe we have not done permanent damage to the environment but rather have produced a much needed supply of energy and helped Alberta's economy by the existence of this valuable facility.

We believe that the existing regulations controlling the emission are at such a level that no damage is being done to the environment and any increase in stringency would not be of significant benefit to our surroundings, but would place an unnecessary additional financial burden on an Industry which is called upon to supply an increasing amount of highly desirable product at continually increasing costs of finding and producing.

E. Wichert
Wildcat Hills Unit Superintendent
Petrofina Canada Ltd.

September 18th, 1972.

QUESTIONING BY THE AUTHORITY

DR. W.R. TROST

On page 3 you mentioned that college students studying the environmental sciences had investigated the environmental effects in the area of the plant. Did they give you any of the reports on it?

MR. E. WICHERT

We did not request them to give us formal reports, but I was curious as to what they'd found; one of the students happens to be taking in these meetings so I asked her earlier to give me a brief review of what they had found. Perhaps she could give this reply to this question. The student that's coming up is Miss Iris Chaba, who is going to Mount Royal College. The course she's taking is Environmental Quality Control.

MISS I. CHABA

After doing this study of the Wildcat Hills sulphur plant we found that there weren't any detrimental effects to the environment around the plant. But we did this survey over only a very short period of time, and so we cannot really say if this would apply to a long-range study.

DR. W.R. TROST

When did you do it?

MISS I. CHABA

We did it in January and February of 1972, and we've got some of our results right here.

DR. W.R. TROST

Would you leave us a copy? Thanks very much.

MR. E. WICHERT

In addition to this group of students that studies our plant, we're also co-operating with a group at S.A.I.T. by allowing them to put their own candle stations inside our plant area. Periodically they come out, change them and analyze them in their labs. This is not only to train students but also to see what's actually happening inside a plant area.

DR. W.R. TROST

Could you give us some data, some statistics, Mr. Whchert? What is the composition of your feed gas to the sulphur plant, in terms of hydrogen sulphide?

MR. E. WICHERT

To the sulphur plant it's 38-39% H_2S and the balance is CO_2.

DR. W.R. TROST

So it's a fairly sour gas?

MR. E. WICHERT

Well, no. This is to the sulphur plant. At the front end of the sweetening facilities the total acid gas content is 4% H_2S and 6.5% CO_2.

DR. W.R. TROST

That's as it comes out of the well?

MR. E. WICHERT

Right.

DR. W.R. TROST

Then, your production of sulphur will not be so very large. What is your production of sulphur per day?

MR. E. WICHERT

At the maximum through-put rate it's on the order of 170 tons per day.

DR. W.R. TROST

Then your emission of sulphur dioxide per day?

MR. E. WICHERT

The emission of sulphur dioxide is on the order of, at the high rate, twenty to twenty-four tons per day.

DR. W.R. TROST

You've generally supported the C.P.A. brief so I don't have to question you on that part of it, but do you have any H_2S odor problems around the plant?

MR. E. WICHERT

Occasionally we do, yes.

DR. W.R. TROST

And what part of the plant does that arise from?

MR. E. WICHERT

I recall one instance. We had a leaky gasket on a tank hatch; some mercaptan and hydrocarbon odors were coming out of this source, and we traced them down and corrected it.

DR. W.R. TROST

I'm assuming from the evidence that you've given that the plant location is used as a picnic ground.

MR. E. WICHERT

Yes.

DR. W.R. TROST

And that there would be times when there are no sulphide funes whatever. Is that right?

MR. E. WICHERT

There would be times when there are no sulphide fumes, that's right.

DR. S.B. SMITH

More with respect to other operations, you have had a very long experience with the public; that is, making freely available the area around the plant presumably has resulted in excellent public relations. The people understand how the plant operates, they use the area, and there don't seem to be any problems. Do you think this has general applicability right across the industry? Should the industry as a matter of course, any plant operation or superintendent, try and involve the local public to a good extent in the operation so they know what's happening?

MR. E. WICHERT

Yes, I think this is a very good policy. The more communication that an operation, whether it's a gas plant or any other operation, can have with the people that live in the vincinity, the more this clears up many misunderstandings, many apprehensions that the people living in the area have. On the whole, I think it's a good policy, yes.

THE CALGARY CHAMBER OF COMMERCE SUBMISSION
TO
ENVIRONMENT CONSERVATION AUTHORITY

Presented by: J. Poyen

Subject: Environmental Effects of the Operation of Sulphur Extraction Gas Plants, Calgary Jubilee Auditorium, October 16, 1972

The Calgary Chamber of Commerce respectfully submits the following statement to the Environment Conservation Authority on the occasion of its public hearing in Calgary on October 16, 1972, on the subject of the environmental effects of the operation of sulphur extraction gas plants in Alberta, with particular emphasis on the subject as it relates to the City of Calgary.

The Calgary Chamber of Commerce addresses itself to two basic consideration

(1) The physical fact of environmental pollution caused by the operation of sulphur extraction gas plants in the vicinity of Calgary, and

(2) The contribution of sulphur extraction plants to the economy of Alberta and Calgary.

In reference to point one above, it should be stated that Calgary is, in effect, pollution free from the emissions from sulphur plants. There are no such plants within the corporate limits of Calgary, and those within a 30 mile radius of Calgary located at Crossfield, Jefferson Lake, Okotoks, Quirk Creek and Turner Valley, have a minimal impact on both atmospheric and water pollution within the Calgary city limits.

Regarding point two, it must be recognized that sulphur extraction gas plants, as an independent industry in the economy of Alberta, are a substantial contributor to the Provincial gross national product in terms of product produced and sold, royalty income generated to the benefit of the citizens of the Province, direct employment and payroll contributions, service and secondary industry support, and ultimately the earning of taxable income.

Of even greater importance to the Provincial economy is the fact that sulphur extraction is necessary to process the large reserves of "sour", or sulphur-laden gas which would, in its untreated state, be a worthless commodity in the national and international energy marketplace.

To take extreme literary license with an old saying: "Let us not be guilty of killing the goose that laid the golden eggs just because she has to relieve herself"

The Calgary Chamber of Commerce Oil and Gas Committee has been provided the opportunity of reading the Canadian Petroleum Association's submission on the subject at hand. We are impressed with the factual, statistical, and technical data contained in that submission and with the forthright statements of policy and conclusions expressed therein and wish to convey to the Environment Conservation Authority our endorsement of that presentation.

It is our conclusion that a fine balance between responsible management-operations control of sulphur extraction gas plants and realistic practical regulations be struck between the industry and the Provincial Government. The objective should be the recognition and preservation of the public interests of the residents of Alberta with the economic well being of the Province harmonized to the responsibilities of our society in providing those intangible quality of life standards which we cherish.

Respectfully submitted,

R. R. McDaniel
President
Calgary Chamber of Commerce

John S. Poyen
Chairman
Oil & Gas Committee
Calgary Chamber of Commerce

JSP:mjh

QUESTIONING BY THE AUTHORITY

DR. W.R. TROST

There is just one question that I have in mind. If there are environmental effects of a difficult sort associated with the operation of the gas plants, they're most likely to have their impact on rural areas. The cities are apt to be, in a general way, benefiting from the whole operation since the positive qualities that you mentioned are most apt to accumulate in the city.

MR. J. POYEN

Correct. I might try to get a little out of your context and suggest that, over the period of the last twenty years when gas plants other than Turner Valley were first built and have been in operation in Alberta, the industry has come a long way in developing and accomodating itself to the community, whether it's the rural community or the broader community of Alberta. I think in those early days the industry required certain discipline. The industry in those days did not accept on its own some of its responsibilities which it could voluntarily have accepted. However, I think in that twenty-year period that with the prod of well-designed, practical regulation and effective administration of those regulations, the industry has come a long way. I think it has learned some lessons on its own and I honestly believe the industry is prepared to accept a more responsible position, both from the prods of regulatory authorities and from its own management and its own people operating the plants, and to accomodate itself better within the community in which it's located.

Submission of TEXAS GULF, INC.

Regarding Environmental Effects of the Operation of Sulphur Extraction Gas Plants with Particular Reference to the Okotoks Gas Processing Plant.

to

ENVIRONMENT CONSERVATION AUTHORITY HEARING

CALGARY, Alberta - October 16, 1972

PRESENTED BY: E. Plum

INTRODUCTION

Texas Gulf, Inc. participated in the preparation of the Canadian Petroleum Association submission and we fully endorse the Conclusions and Recommendations of the CPA Report.

Texas Gulf operates the field and the gas processing plant at Okotoks on behalf of Ecstall Mining Limited, a subsidiary of Texas Gulf, Inc., and their partners, Shell Canada Limited and BPOG Operations Ltd. The ownership participation is:

Ecstall Mining Limited	37-1/2%
Shell Canada Limited	25%
BPOG Operations Ltd.	37-1/2%

The plant is one of the oldest recovery units in Alberta, having started operations on June 1, 1959. It was designed for a raw gas inlet rate of 30 million cubic feet per day and a sulphur production of 370 long tons per day. Condensate recovery was not included in the original design and the hydrocarbon liquids produced at each well were recovered in the field by Devon-Palmer, then the field operator.

The plant inlet pressure has dropped from 600 pounds per square inch in 1959 to a present pressure of 450 pounds per square inch. Raw gas feed has decreased to an average of 27 million cubic feet per day and the average sulphur rate is now 345 long tons per day. Approximately 60 barrels per day of condensate are now recovered at the plant and only partially sweetened. It is sold at a distress price. A small amount of aromatics are also recovered and sold.

The acid gas content of the feed gas to the plant is 34% hydrogen sulphide and 11% carbon dioxide. Another 8 - 10% of the gas is used for plant and field fuel. This amounts to an original gas shrinkage of 55%. The remaining residue sweet gas averaging 11.5 million cubic feet per day is sold to Canadian Western Natural Gas and consumed primarily by customers in Calgary.

OPERATIONS

Monoethanolamine is used in the sweetening facilities to remove the hydrogen sulphide and carbon dioxide from the inlet gas. Silica gel dehydrators dry the residue gas. Approximately 19 barrels per day of aromatics are now recovered from these dehydrators.

The sulphur plant is divided into two parallel trains, each having two converter beds or Claus reactors. The average recovery efficiency of the trains has been between 94 and 95%. In 1959 when the plant was put into operation an approval was issued embodying a 250' incinerator stack. It guaranteed a ground level concentration of less than 0.2 ppm of sulphur dioxide as calculated by the Sutton Equation. In 1967, Energy Resources Conservation Board Approval No. 1398 was issued requiring a 93% recovery at a maximum sulphur emission rate of 26.2 long tons per day.

This plant has a unique feature in that, except for the months of July and August, the feed rate is very constant throughout the year and now solely depends on the field capabilities. This steady rate allows optimization of each process unit and virtually eliminates plant upsets and flaring. Our records indicate that gas was flared only once in the last two years and that the amount of sour gas was less than 500,000 cubic feet. During the warm months of July and August our sales gas contract states that Canadian Western is obliged to accept only one-half the normal plant load. The Provincial Boilers Branch has approved a two-year turnaround schedule for vessel inspection and therefore the plant is normally shut down and started up biannually. In addition, plant upsets have been very infrequent over the past 13 years.

ENVIRONMENTAL ASPECTS

Wellhead data are telemetered into the control room and help to supervise the leases. The field is also supervised manually during the day shift. The system sounds an alarm for wellhead or heater house gas leaks. It indicates if the wells are shut in for high or low pressure, high or low temperature, and whether the field has been closed in by the emergency shutdown system. It allows the wells and the field to be shut down from the control room. All of these functions are controlled for the protection of local residents and the environment. Also, in accordance with a recent ruling of the Energy Resources Conservation Board, downhole safety shutoff valves were installed in three wells in 1972.

Sulphur plant efficiencies are determined by the Tutweiler method and by gas chromatographic analyses. Also, recoveries are established by metered gas to the trains and sulphur produced in the rundown pits. A continuous stack emission monitor records the amount of sulphur in long tons per day being emitted to the atmosphere through the 250' stack, also helps to optimize the sulphur plant efficiencies, and is used for plant control and sulphur balance calculations.

With regard to our concern for the effects of the plant on the environment, Texas Gulf began yearly false color infrared photography of the area in 1969. These photographs have been interpreted by Dr. Holmes and he has reported that they do not indicate any ill-effects on the local vegetation from the plant operations except in the sulphur storage area. This, of course, is the effect of sulphur dust on the grass and trees and is strictly confined to Texas Gulf's property. In 1970 Texas Gulf retained Mr. R. E. McAllister, a member of the Alberta Institute of Agrologists, to conduct a thorough survey in the immediate vicinity of the Okotoks plant. At that time he found that the sulphur had affected three sites favorably, in that it lowered the pH of the predominantly basic soil to a pH of between 6.4 and 7.8. Texas Gulf leases the land around the plant and sulphur storage area to a local farmer and to date he has not reported any ill-effects to his cattle due to sulphur.

As early as 1963 Texas Gulf conducted a sulphur dustfall survey at Okotoks using the services of the Research Council of Alberta. They reported that if any sulphur dust was reaching adjacent property it was insignificant and harmless. In accordance with the Department of the Environment Directive AMD 72-3, dated March 23, 1972, Texas Gulf has positioned ten dustfall cylinders around the plant. The sulphur dustfall is analyzed monthly and reported to the Department of the Environment.

In 1971 the Energy Resources Conservation Board informed Texas Gulf that ground level concentrations of sulphur dioxide on the hills to the north of the plant could get as high as 0.545 ppm over a half-hour period, using the Pasquill Equation, which takes into account the variation of terrain and certain meteorological conditions. Texas Gulf offered to monitor the hills to confirm if these concentrations do occur. A few instantaneous high peaks were recorded when the wind was from the south, but at no time during the three and one-half months survey did they exceed the Federal Government ambient air standard of 0.17 ppm in any 30-minute period. A higher percentage of high peaks was recorded when the wind was from the north, or from the direction of the City of Calgary, than from the direction of the plant. Texas Gulf maintains eight sulphation cylinders around the plant and our results are cross-checked with the results of five government reports. The monthly analyses of total sulphation and total hydrogen sulphide accumulation are reported to the Energy Resources Conservation Board and the Department of the Environment.

Process water is separated at the plant and reinjected into an underground formation at a rate of approximately 38 barrels per day. Boiler blowdown water amounts to 130 barrels per day and, together with 36 barrels of backwash water from the zeolite softeners, it is impounded in a lagoon. Overflow from this pond passes to a flat plain below the plant. It is sampled monthly and the analyses are forwarded to the Department of Health. To date the only specification that is not always met is threshold odor; a difficult quantity to specify.

A small stream runs through the flat plain and flows into the Sheep River. Last month (September) after Dr. Holmes had prepared his report for this ECA Hearing, the stream was rerouted away from the sulphur storage area and a retention dike and pond were built to collect the runoff water for treatment before release. In the very near future we intend to combine the lagoon water with pond water (one being basic and the other acidic) or make application to inject the plant utility waste water into the underground reservoir.

Texas Gulf conducts safety training programs similar to those presented to the Authority by other companies. Our safety record has been excellent. We have received a minimum number of complaints from neighbors and believe that we are good corporate citizens.

CONCLUSION

Texas Gulf believes that the plant is presently being operated at an average optimum efficiency of 95% with the existing equipment. The new Energy Resources Conservation Board guidelines require that the efficiency be increased to between 96 and 96.5%. Only by adding more equipment can this level be reached. An outside Canadian contractor has estimated that a third converter bed would require a capital expenditure of approximately $400,000 plus a slight operating cost increase.

Texas Gulf would like to continue to operate under its present approval. We do not believe we are causing any permanent adverse effects on the environment and prefer to be regulated by ground level concentrations rather than by the quantity of sulphur in stack emissions.

AN ENVIRONMENTAL STUDY

# of the

OKOTOKS SULPHUR EXTRACTION GAS - PLANT AREA

for

TEXAS GULF INCORPORATED

TO SUPPLY DATA TO

THE ENVIRONMENT CONSERVATION AUTHORITY

FOR HEARINGS AT

CALGARY, ALBERTA

PRESENTED BY: DR. R. M. HOLMES

ERA INSTRUMENTS LTD.
P.O. BOX 3444 STN. "B", CALGARY, ALBERTA. TELEPHONE (403) 276-5001

September 14, 1972

Mr. E.W. Plum, P.Eng
Assistant Manager
Texas Gulf Incorporated
1970 Elveden House
P.O. Box 870
CALGARY, Alberta

Dear Mr. Plum,

The attached is a document that details our findings in connection with your request that we study the environment of the Okotoks gas plant as outlined in your letters of August 2nd, and September 5th.

Report copies do not contain the relevant 9" X 9" FCIR frames. However, overlays are included to which designated FCIR frames can be fitted. Such frames will be retained by Texas Gulf Incorporated.

If questions arise out of our report, please contact us.

Sincerely,

ERA INSTRUMENTS LTD.

R. M. Holmes
President

RMH:KMS
Enc.

PREFACE

Public hysteria about the environment shows very welcomed signs of moderating. More opinions are based on fact, and emotion seems to be a less important ingredient of the decision making and environmental management process. The Environmental Conservation Authority has called hearings in Alberta to bring pertinent data and opinions together on a number of subjects. The possible environmental degradation due to emissions from sulphur extraction gas plants in Alberta is the subject now at hand and the following pages were assembled to provide a scientific data base for the hearings in connection with the Okotoks gas plant of Texas Gulf Incorporated. Hopefully the hearings will stimulate regulations that are less emissions-oriented and pay greater concern to the environment.

"The figures referred to in this submission are listed below. Those figures indicated by an asterisk are not reprinted in these proceedings but are available for viewing at the Information Center, Environment Conservation Authority, 9912-107 St., Edmonton, Alt

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AN ENVIRONMENTAL STUDY
# of the
OKOTOKS, SULPHUR EXTRACTION GAS - PLANT

1. INTRODUCTION:

Another new morality has arisen. It has been recently referred to as environmental morality. It says that the environment is not completely our own. It belonged to those that proceed us and will yet belong to those who follow. The proposition goes on to say that because of this, it is morally correct to pass on our environment to those who follow, in improved condition compared to that during our own stewardship.

To be opposed to such a morality is like being opposed to "righteousness", yet to accept and live it in our industrialized society may be more difficult than we now expect.

The earth has finite resources and many reserves will be exhausted during our present life-time. The pressure for locating new stores of fuels, for example, is very great and while the search is in progress the newest morality states that the environment must not be affected. Further, while present stores of fuel are being processed for consumption, the environment must not be degraded.

Aside from legalities, each person or group is primarily responsible in the keeping of its own house. Many groups have reacted to the environmental morality showing very responsible attitudes and have gone to considerable expense to determine the extent of their own environmental influence. Members of the petroleum industry are a case in point. This report is a documentation of a study undertaken by Texas Gulf, Incorporated to determine the nature and extent of the influence of their own gas processing on the environment.

II. ENVIRONMENTAL SENSING & MONITORING:

The management of an environmental program reduces to a very simple concept - one determines what the pollutant is, where it is, how much there is, and what it is doing to the natural systems that absorb it. Management is then involved with many disciplines that have to do with atmosphere, water, soil, vegetation, etc. Natural processes are very complex and overlap greatly. This means,for example, that one cannot study the effect of industrial effluents on the soil without being involved in many physical and biological processes that lead to the emission, transport, and final deposition on the soil of the effluent. After deposition has occured natural processes are then involved that assimilate the effluent into the cycles in nature.

These considerations suggest that so called "classical methods" are no longer sufficient by themselves to provide data that describes the relationships between the effluent and the receiving environment. They must be supplemented by other techniques that have been improved or by new technologies such as those that have been created by the space rush. Such methods fall into two broad categories that may be termed direct or immersion sensing (measurement by contact such as soil sampling or temperature measurements) and remote sensing (measurement without contact such as with a camera or linescanner). Both groups of techniques are often used synchronously to acquire necessary data. The following discussion pertains to those methods that are relevant to this report.

(a) Direct & Immersion Sensing Methods:

While numerous techniques are available in the general technology of direct sensing, several are relevant here. Effluents from gas-plant operations interact with the atmosphere, vegetation, and the soil. Direct sampling may be used to determine the nature and degree of interaction.

Soil sampling is a common technique in agriculture for determining the status of various chemicals concerned with plant nutrition. While soil sampling may appear to be a very simple process, obtaining proper samples is exacting task.

Soils are highly variable over very short distances. In order to overcome the natural variability in soils, many samples should be taken and composited to produce a single sample that could be called 'representative'. Further, the influence of centuries of natural weathering processes has differentiated natural soils into horizons. These layers are formed so that they are recognizable by color, texture and chemical constituents. In the case of soil contamination, sampling must be done according to these natural layers or horizons, not by depth. A trained field man is required to obtain such samples reliably.

In general, six to eight sampling locations are chosen that are representative of the particular site. Excavations or auger holes are made to the desired depth and samples from each position of each excavation are taken and composited. A single sample is withdrawn from the composite which represents the average condition of the soil at that position in the profile for that sampling site. Sites are chosen to provide a picture of soil conditions over the area of interest.

As far as gas plant problems are concerned, the soil parameters of greatest concern are pH, sulphates, conductivity, and free lime concentrations. Sulphur dust and SO_2 are involved in the soil in such a way that an acidic reaction is produced. Sulphates increase, conductivity may increase and the free lime ($CaCO_3$) is reduced or disappears. In extreme cases, the pH may be lowered to the point where plant growth may be seriously retarded. Such effect however are usually very local to the sulphur plant. To place these parameters in an agricultural context, the following data is offered:

pH: degree of acidity.

7.2 - 6.0	optimum range
4.9 - 4.5	strongly acid
9.5 - 8.5	strongly basic

Crop plants may be grown in any of these ranges with the greatest restrictions in the strongly acid and strongly basic ranges where tolerant crops must be used.

Conductivity: Soluble salt concentration, mmhos:

low	2 - 4	most crops unaffected.
moderate	5 - 10	most crops unaffected except legumes.
high	11 - 16	grasses and a few grains unaffected
very high	16	some very tolerant grasses unaffected - no grains survive.

High conductivity generally reflects high levels of sodium salts and/or sulphates.

Sulphates: SO_4

Normally,in western soils sulphates are present as the calcium salt. There is usually little adverse effect on crop growth because of the insolubility of $CaSO_4$. High sulphates near gas-plants is usually an indication that elemental sulphur is"enroute"to a condition which causes a low pH.

Free Lime: $CaCO_3$

Western soils are usually high in free lime and this reflects the geological origin of the soils but usually has little effect on crop growth. Well developed soils normally have high lime in the B_1 and C horizons. Absence of free lime suggests susceptibility to high acidity.

In all nature, the soil system has the greatest ability to absorb and decompose waste materials. Soil is enormously complex, and if the various soil processes are not over-taxed, it can be used to dispose of many wastes.

Vegetation Surveys and Sampling are conducted in environmental research to determine the nature and degree of plant stress. SO_2 is the effluent from gas plants that is of the greatest concern as far as vegetation is concerned. Because plants grow in a complex continuum of soil and atmosphere, the response of plants to external stress is rather complicated and manifests itself visually in many ways. This is roughly synonymous to the several ways that a given disease can influence many persons.

Plant change due to subjection to SO_2 has a common theme with many variations that are the result of previous stresses, water supply, light intensity, nutritional status, and so forth. Continual exposure to non-lethal levels of SO_2 produces a particular type of symptom (chronic). Plants exposed to sudden and short near-lethal or lethal doses of SO_2 display another set of symptoms (toxic). Visible chronic and toxic SO_2 symptoms are rarely identical in any species. In Alberta, there are very few documented cases of SO_2 stress in natural native stands of trees or crop plants.

A further complicating feature of vegetation surveys for stress analysis is that many other stresses can imitate SO_2 damage. Insects, nutritional disorders, NO_2, O_3 all can produce symptoms resembling SO_2 influence. Needless to say, considerable research needs to be done in this area.

Plants have the capacity to absorb harmful substances, suffer, and then recover depending on the dosage. To be completely accurate, samples should be laboratory examined.

Plant SO_2 stress, if present, is likely to be found very near the gas plant or some distance down wind where the stack effluent plume comes to the ground. ERA has previously noted such symptoms on ridge crests and hill sides facing the gas-plant, but rarely on flat land at any distance from the processing plant. Natural stands of trees and trees in shelter belts are more likely to show stress than agricultural crops. Stress symptoms, again depending on dosage, are more easily found in spring and summer than in the fall. The writers have noted that in late August populus under severe heat and water stress showed no response to the presence of a heavy dosage of SO_2.

Other data on this subject are available from the literature.

Air Quality Measurements may be carried out with a number of instrument systems that sample and analyze for particular effluents. SO_2 is recovered and subjected to a wet chemical analysis that can produce accurate real time, long time measurements. It must be remembered that such data is a point measurement, and as such could lead the operator into serious errors if improperly interpreted. The state of the art in air quality measurements is very high, and very small concentrations of irritants can be detected and traced to the source.

Another facet of air quality is that associated with the dynamic and physical state of the atmosphere. Immersion or direct methods are available for completely charactarizing the physical nature of the atmosphere in space and time. The dynamic condition (turbulence, lapse rates) determines completely the degree of diffusion and dispersion of stack effluents. Airborne and tower instruments can give highly accurate and detailed information. Tower data is a point measurement and has the disadvantages inherent in such information. Aircraft-acquired data is the better method since an aircraft is very mobile, and moves at high speeds. These data will provide a comprehensive picture of effluent dispersion rates in space and time under a host of meteorological conditions.

Additional information on the dispersion of plumes related to atmospheric conditions will be presented in a later section.

(b) Remote Sensing Methods:

Radiation from the sun occurs in all wave lengths from gamma energy to very long radio waves. Some of it is affected by the presence of the ocean of atmosphere covering the earth. In some frequencies, radiation penetrates to the surface relatively unaltered in other frequencies, the atmosphere is completely opaque. (The shortest wave lengths are trapped in the magnetic field of the earth and do not reach the surface in very great quantities). Those wave lengths that are permitted to penetrate to the surface do so through what are called "atmosphere windows". Visible energy, as well as some parts of the ultra violet and infra-red spectrum, is transmitted to the surface through such "windows". Figure 1 shows a qualitative relationship between wavelength and transmission of radiant energy. Note that the atmosphere is less transparent to visible energy than to the transmitted IR. In the IR, there is a large "window" over the interval 3 - 5.5 microns, and from 8 - 14 microns wavelength.

All objects and surfaces reflect and emit energy into space. Reflection occurs only during periods of illumination. Emission, conversely, takes place at any time if the object has a temperature above absolute zero. Figure 1 illustrates that the higher the temperature of the object, the greater is the emission rate in the IR, (proportional to the fourth power of the absolute temperature), and the greater is the shift of peak emission rate toward the shorter wave lengths. At temperatures normally encountered in

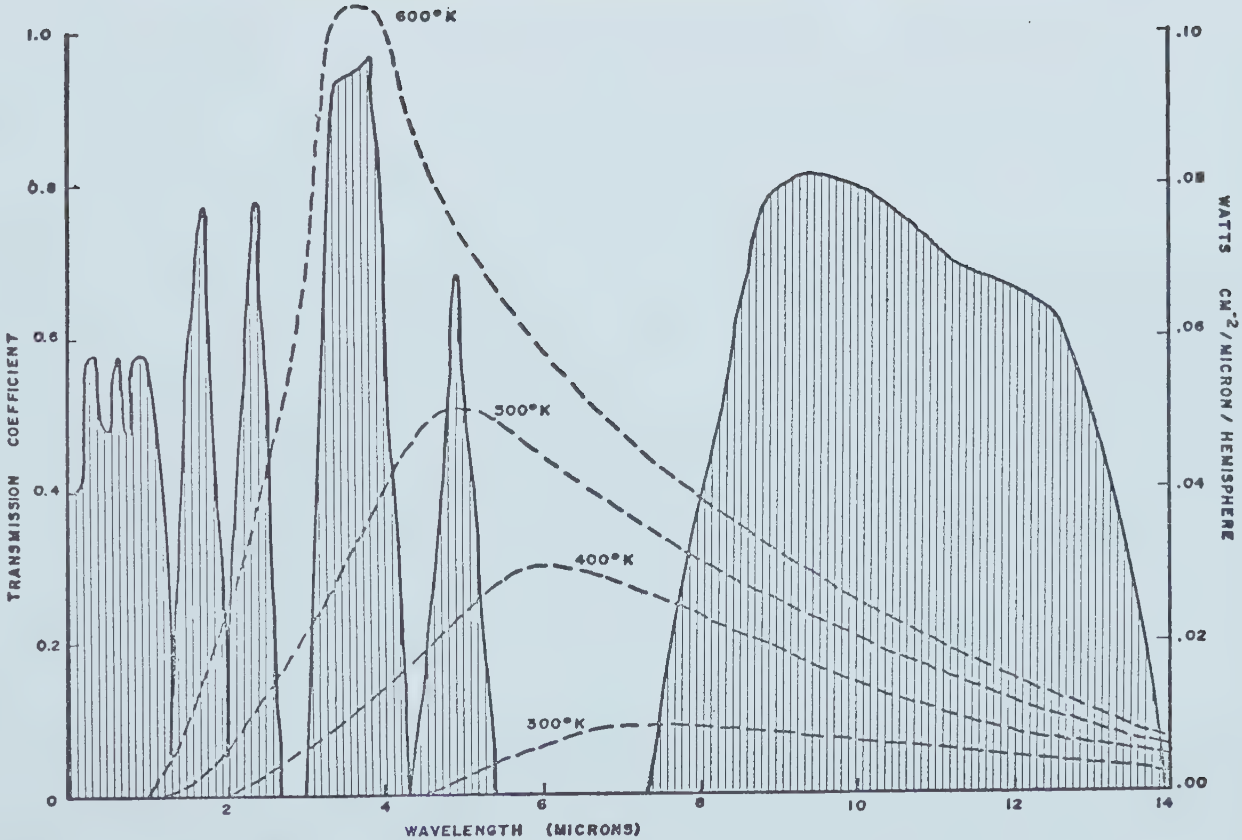


FIGURE 1. TRANSMISSION SPECTRA of the ATMOSPHERE (IR) and BLACKBODY RADIATION.

nature, the peak is in the 8 - 14 micron "window".

The nature of radiation processes near the surface of the earth determines, in very large measure, the character of the surface, whether it be tundra or desert. Notice in Figure 2 that radiative processes are enormously different from night to day. Great variations also occur from day to day. Day-time reactions are dominated by solar radiation input, whereas the largest night-time process is back radiation (emission) from the surface into space. Notice that a host of small but complex radiation reactions occur at the immediate surface, night and day.

The existence of all these radiation processes permits the detection and measurement of the characteristics of objects and features on the surface by using suitable sensors. Such instruments may detect the emitted (day and night) energy as well as the reflected (day only) part of the spectrum. These sensors normally operate remotely, e.g. without contact with the target, and are known as remote sensors. They can be very simple or sophisticated systems and can be made sensitive to selected parts of the spectrum. Certain films for example, respond to visible energy, but other metallic sensors detect only IR radiation, etc. Figure 3 presents a description of the electromagnetic spectrum and some of the sensors used to detect parts of the spectrum.

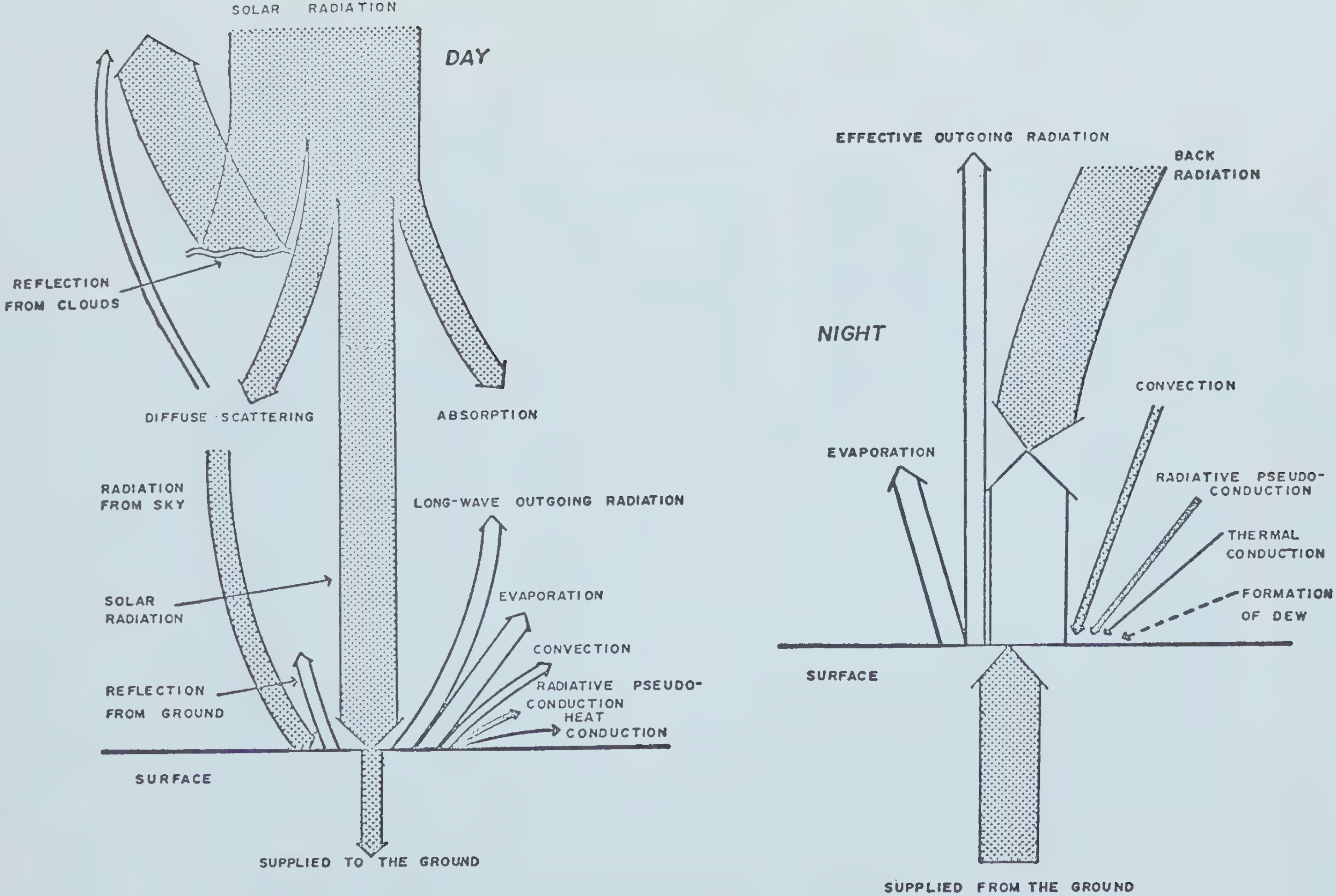


FIGURE 2. NATURAL RADIATIVE PROCESSES AT AND NEAR THE EARTH'S SURFACE.

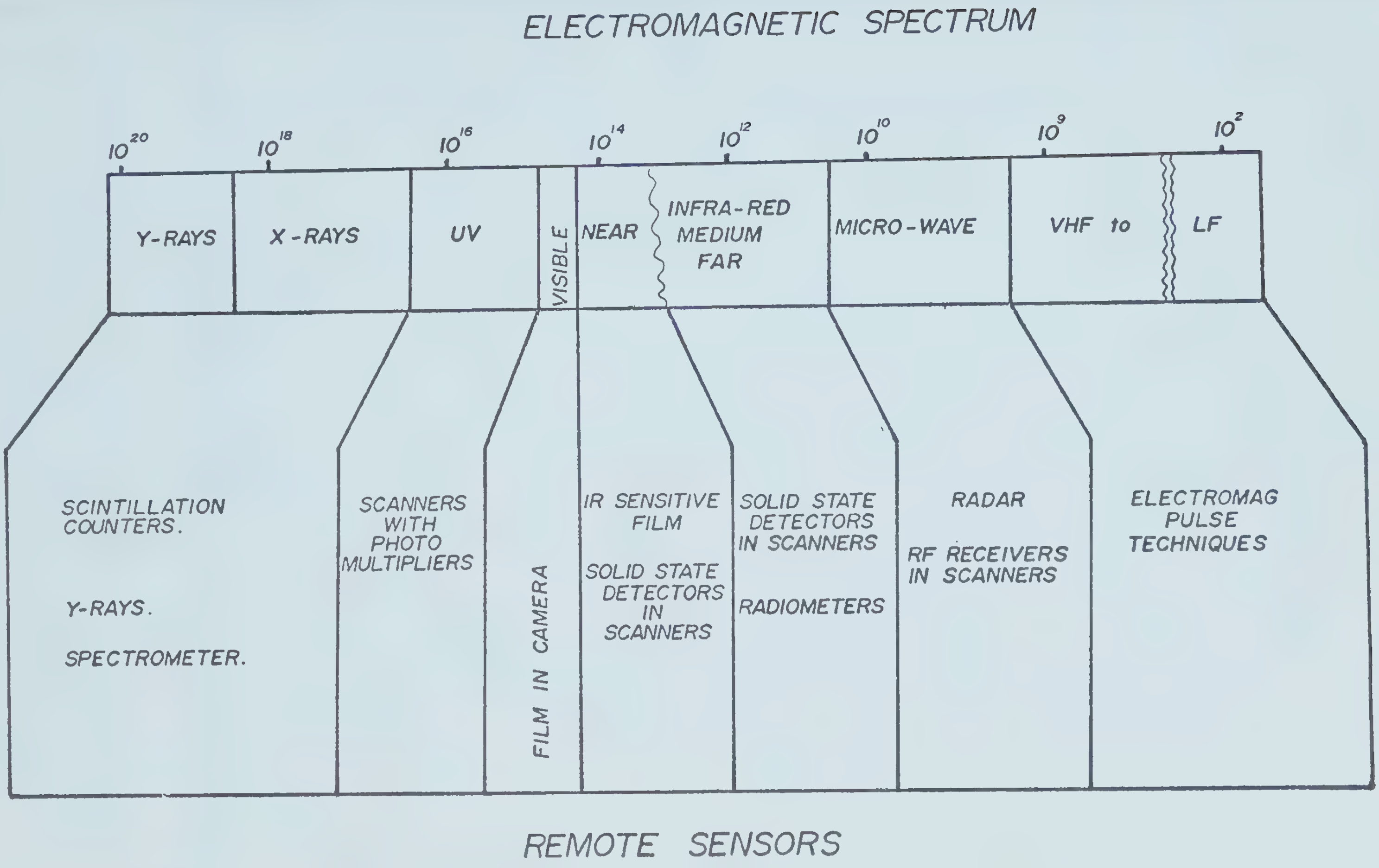


FIGURE 3. THE ELECTROMAGNETIC SPECTUM and REMOTE SENSORS THAT ARE USED TO DETECT SPECIFIC ENERGY WAVELENGTHS.

It is necessary to note that the emission and reflection processes at the surface determine how objects "appear" to sensors. Figure 4 suggests the magnitude of each process with respect to wavelength. Notice that reflectance diminishes with increasing wavelength up to about 3 microns, whereas emission increases from about 1 micron with some over-lap.

Figure 5 is a graphic presentation of the reflectance characteristics of four common materials. The curves show why grass appears a different color than soil or asphalt. Every object can be similarly categorized. Each has its radiation peculiarities and this makes one object distinguishable from another. Note in Figure 6 the characteristic reflectance curve of vegetation with a peak in the green and a large peak in the red and near IR. Similarly, Figure 7 presents the spectra of silver maple at four periods during the summer season. These curves demonstrate quantitatively the change in reflectance of this vegetation that accounts for the seasonal change in appearance (color) from May to November. Notice further that if a given sample of vegetation undergoes a physical change or is subjected to stress, the spectral details of the sample also change. The sycamore leaf, for example, has much higher emittance and reflection in the short IR when dry than when fresh. This explains the unusual change in appearance of the leaf on drying (see Figure 8).

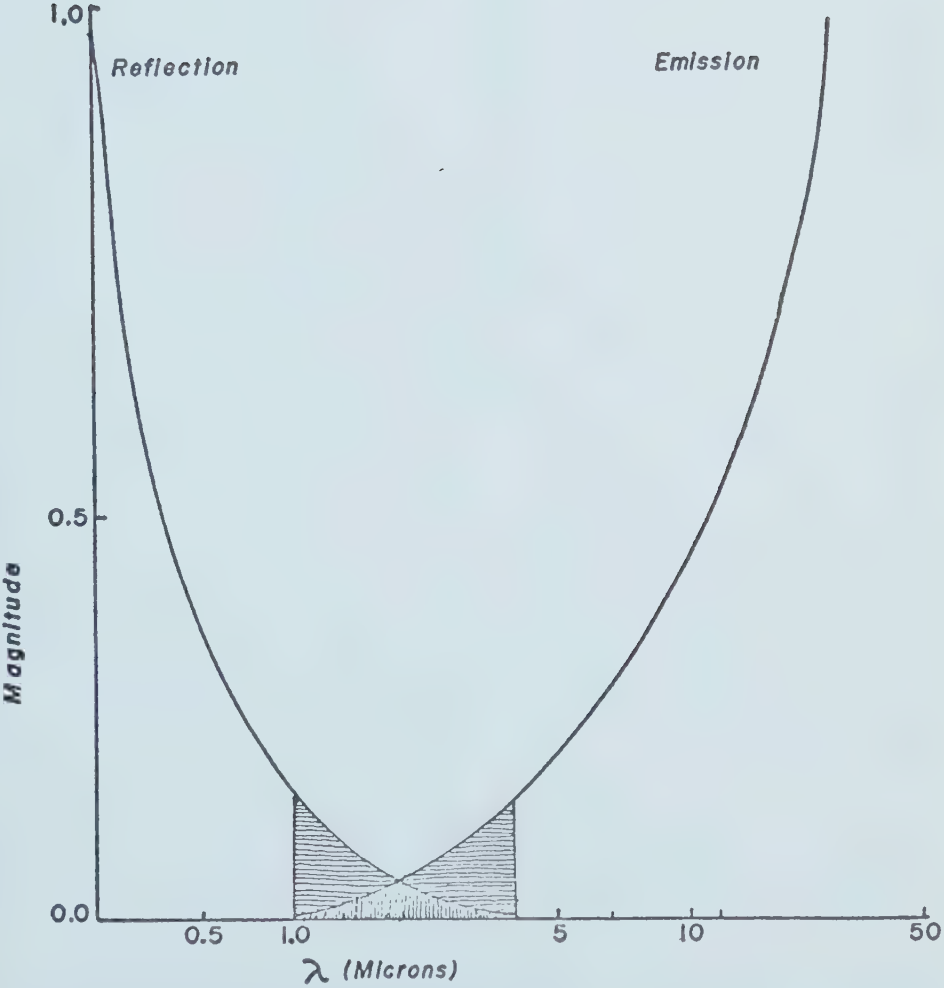


FIGURE 4. GENERAL RELATIONSHIP BETWEEN EMISSION AND REFLECTION VS ENERGY WAVELENGTH.

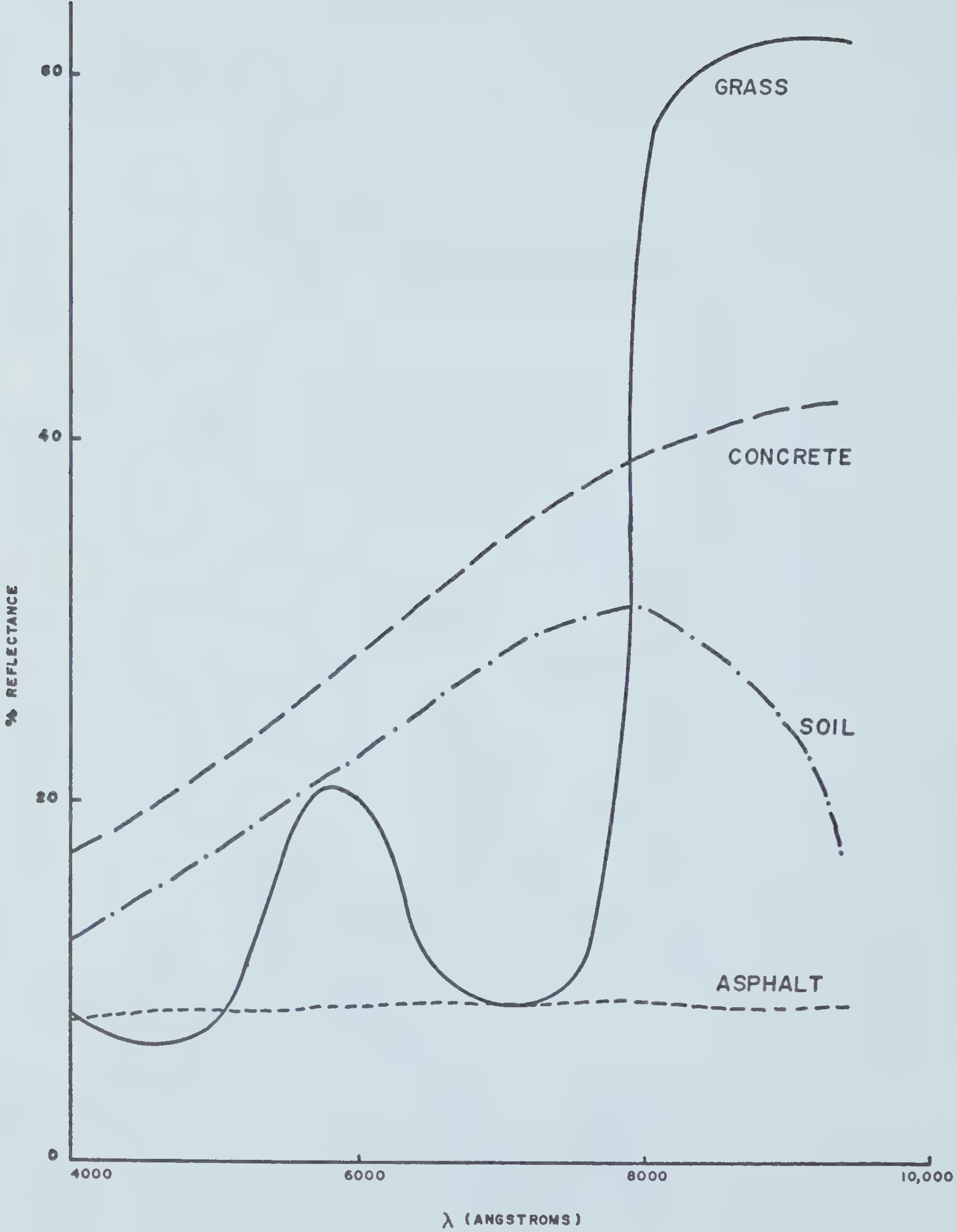


FIGURE 5. SPECTRAL REFLECTANCE OF VARIOUS MATERIALS.

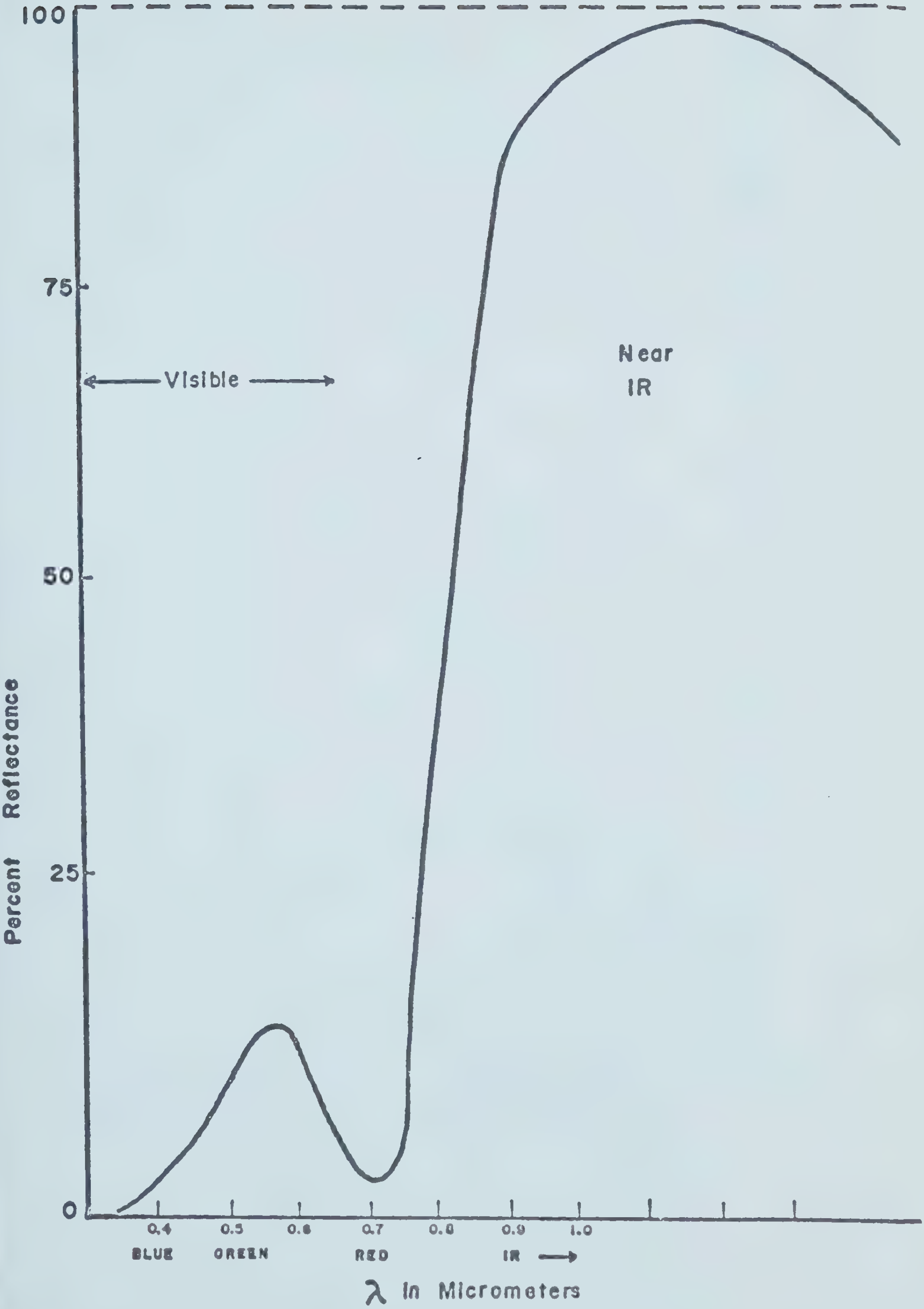


FIGURE 6. RELATIVE REFLECTANCE FROM VEGETATION.

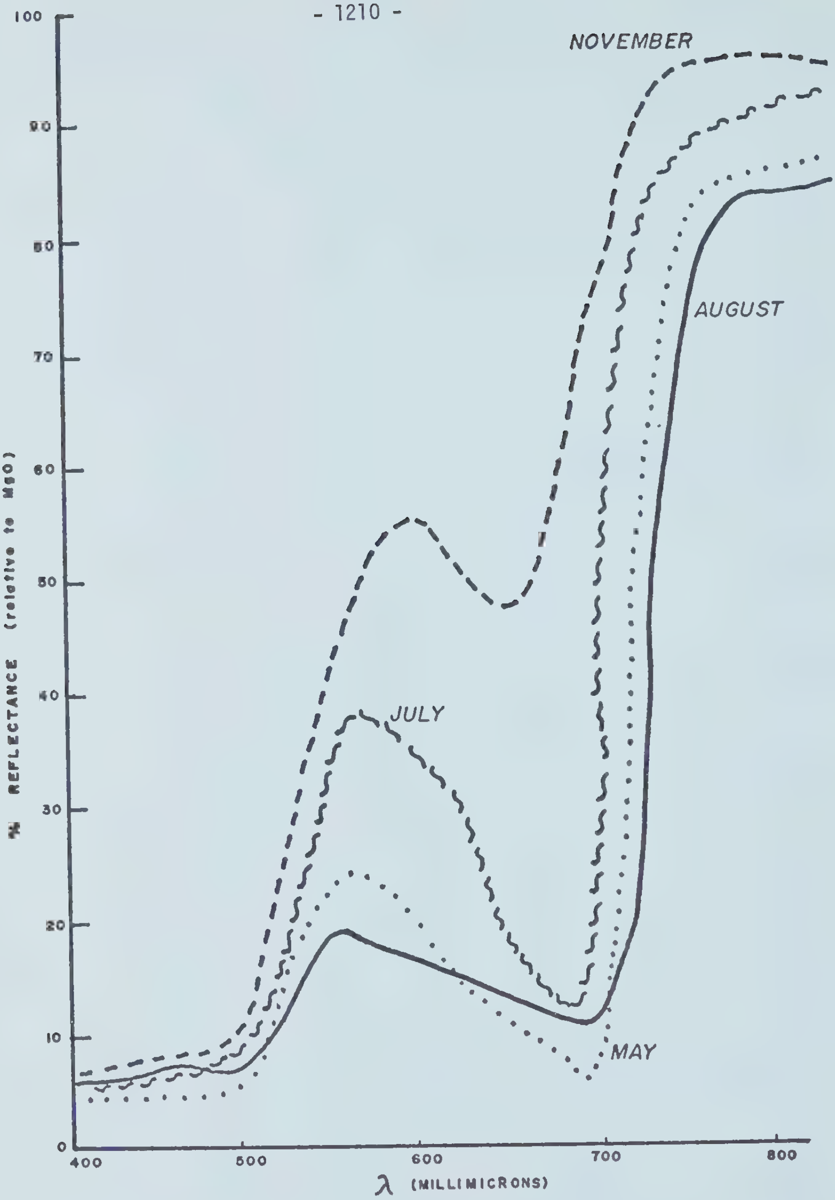


FIGURE 7. Spectral Reflectance of Upper Surface of Fresh Silver Maple Leaf at Various Times During Growing Season.

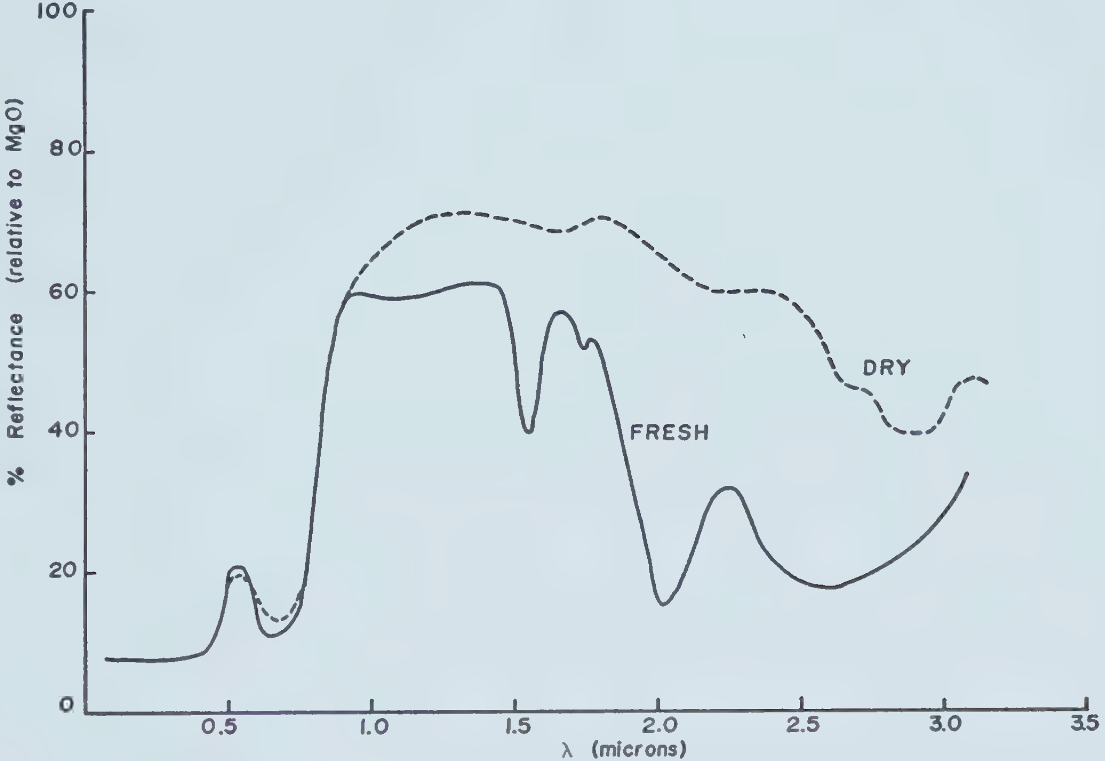


FIGURE 8. Spectral Reflectance of Upper Surface of Sycamore Leaf Before & After Drying.

The Camera is a common remote sensor used for the detection of target reflectance. Films and filters are now available that are very wavelength-sensitive and selective. Dyes and chemicals on films can be formulated to give specific responses, some of which are shown in Figure 9. Both films shown are for aerial camera use but are for different purposes. The infrared film has extended response into the visible red and the short IR (sometimes referred to as photographic IR). This produces a very strong red tone in the image. Figure 6 suggests that since vegetation generally reflects very strongly in the red, this film could be used to photograph certain features of vegetation. Since the image tones are not consistent with real colors of vegetation, the film is often referred to as false color infrared or FCIR film. An example of this imagery is shown in Figures 44 & 45. which present the true color and false color renditions of the same scene near Calgary. Notice the variable red tones of the vegetation which correspond to the different species of plants. Figure 10 provides an insight into the nature of the relationship between FCIR film and vegetation. It is a graphic illustration of the radiation response of a typical deciduous green leaf. Notice that green energy is reflected directly from the surface giving the leaf its characteristic green color. However, the red part of the energy is reflected mainly from the spongy mesophyll. When it is vigorous and turgid, the amount of red reflected will be large compared to that which would occur if these cells were under physiological stress. Some types of plant stress cause the

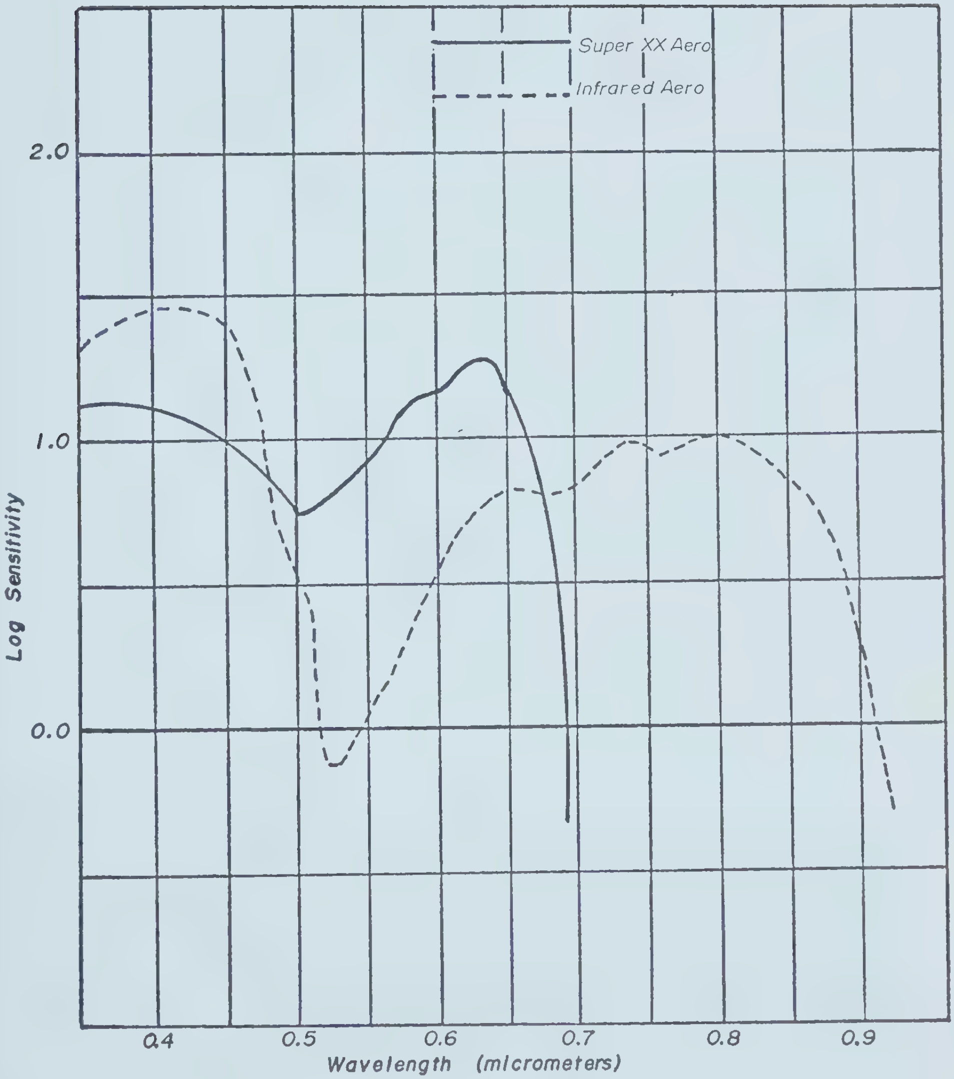


FIGURE 9. Approximate Sensitivity Curves for Two Air Photo Emulsions.

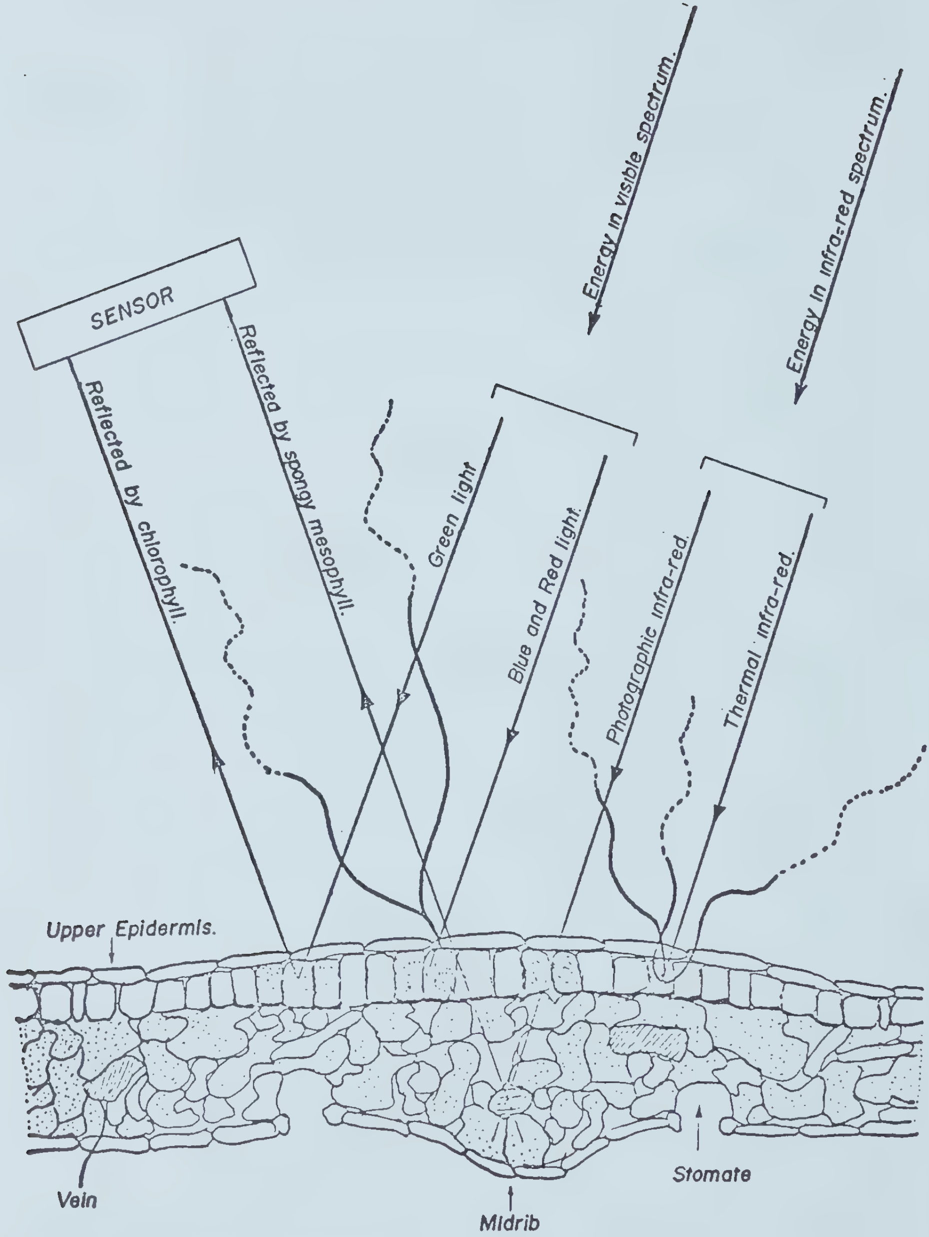

Energy in visible spectrum.
Energy in infra-red spectrum.
SENSOR
Reflected by chlorophyll.
Reflected by spongy mesophyll.
Green light
Blue and Red light.
Photographic infra-red.
Thermal infra-red.
Upper Epidermis.
Vein
Midrib
Stomate

FIGURE 10. Disposition of energy falling on a deciduous green leaf.

reflected red energy to shift toward the greyish, and pink tones. Other stresses impart a brown or green tone to the target. It is therefore possible to use FCIR film to monitor some types of vegetation stress.

Notwithstanding the wide use of films and cameras, they are limited entirely to the sensing of visible and "photographic IR" energy. However, the total energy available for detection is actually very broad, and also includes long wave ultra-violet, much of the infra-red, nearly all of the microwave and the longer radio wavelengths. Atmospheric attenuation limits the quality of detectable energy to these wavelengths. Figure 4 further shows that for wave lengths longer than 3 microns, emission rather than reflection, is measured.

The atmosphere is transparent to IR in the 3 - 5 and 8 - 14 micron ranges. To detect this emitted energy, rather exotic alloys and mixtures of rare elements are required. Some of them must be cooled to the temperature of liquid nitrogen. The instrument used is called a linescanner and it is normally airborne. It consists of a unique optical system composed of a rotating mirror, and folding mirrors. The sensor is placed in the prime focus of the optical system so that all IR energy from the scene is focused on to it as the rotating mirror scans the scene below. Figure 11 shows the essential components of a linescan system. Data are usually recorded on magnetic tape for future processing.

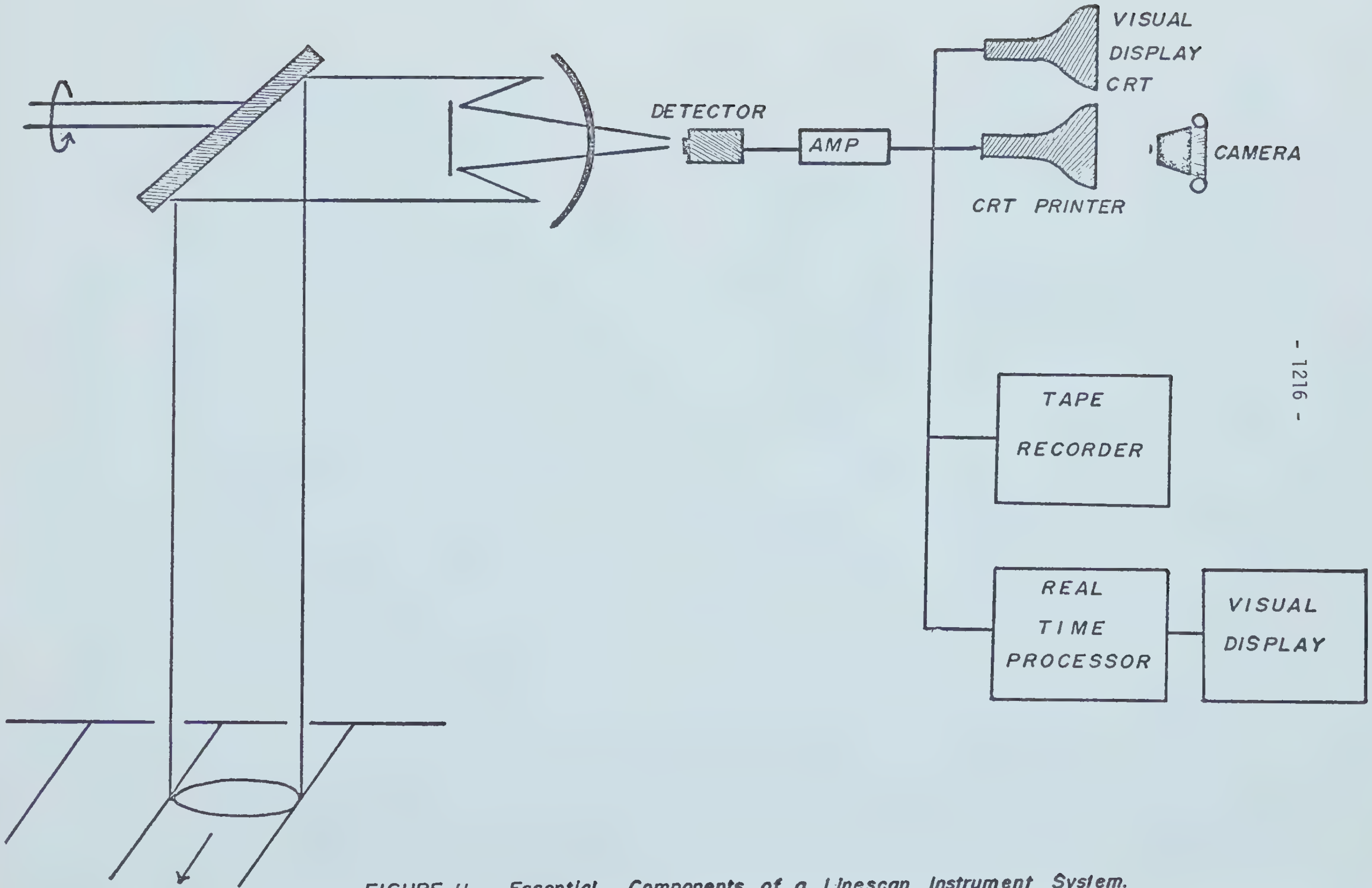


FIGURE 11. Essential Components of a Linescan Instrument System.

The geometry of the system is such that the forward motion of the aircraft coincides with the successive scans of the rotating mirror, and the scene is examined one line at a time, as shown in Figure 12.

Linescan and filmed data are concerned with two entirely different kinds of information. Useful data is available from both methods, but in order to obtain the full benefit from them, they must be used with judgement. Many kinds of environmental stress are discernable with a linescanner but completely avoid being recorded on films. Yet, at other times of the year and depending on the stress anticipated, FCIR or other films provide the data required.

The data in Figures 6 & 8 suggest that there is much detail in vegetation response to stress in wavelengths in the IR regions. All objects have a temperature that is in relative equilibrium with the environment. Healthy plant tissue has an equilibrium temperature which is moderated by the character of the plant physiology (e.g. metabolism, respiration rate, transpiration). If the physiology is upset by stress from water shortage, heat surplus, disease or insect attack, or industrial effluent dosage, the temperature of the plant will change. Such symptoms are only measurable in the thermal IR energy range, and can be related to the type of stress.

Remote sensing is a rapidly advancing technology and new methods are coming forth continually. The art of environmental stress

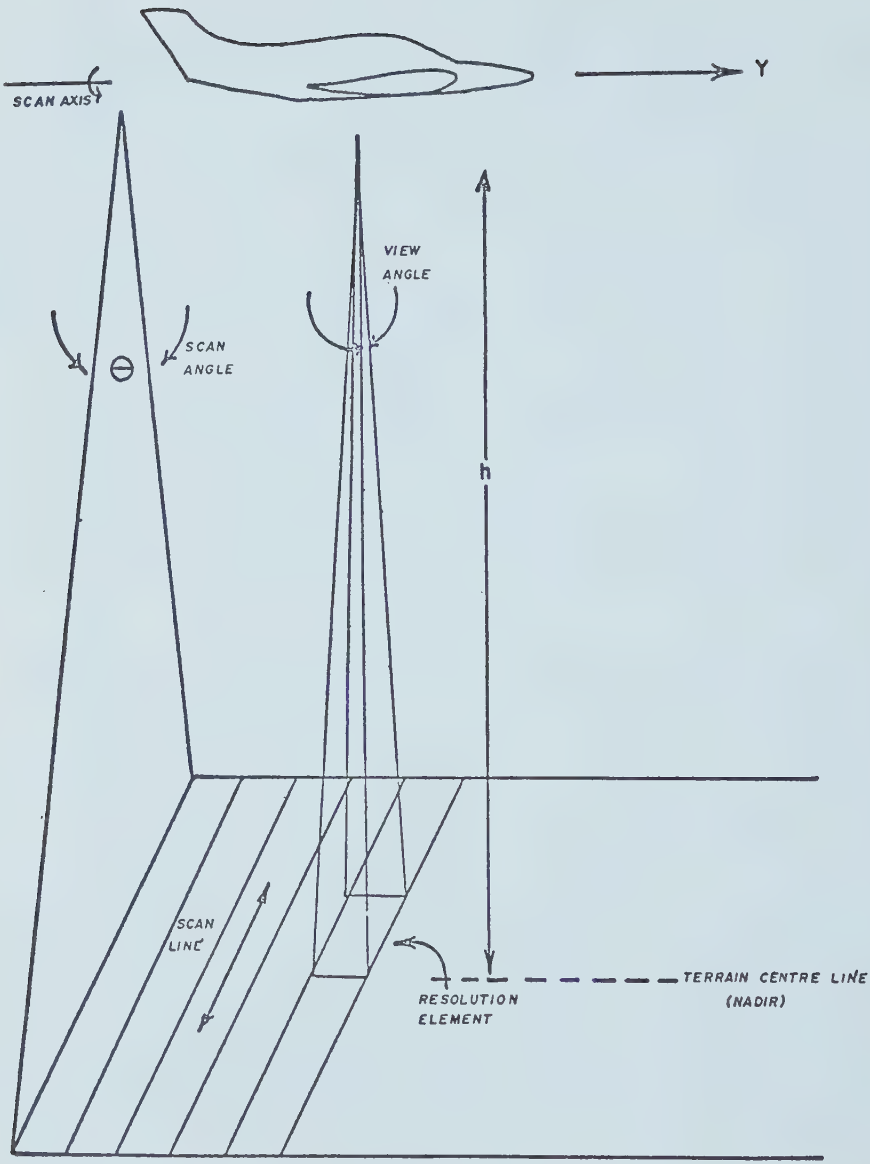


FIGURE 12. TYPICAL LINESCANNER GEOMETRY

identification is a particularly important facet and will see many advances in the near future. Another group of remote sensors that are relevant to this report are those that are sensitive to spectral shifts resulting from the interaction of radiation with certain gases. One instrument of this type is called the correlation spectrometer. This instrument has been programmed to recognize the normal spectrum of ultra-violet at about .351 microns wavelength. If the energy has passed through an atmosphere that contains SO_2, the spectrum of ultra-violet at this wavelength shifts to the shorter wavelengths. The instrument is designed to recognize this spectral shift, and relate it quantitatively to the amount of SO_2 in the beam path. The ultra-violet sources normally used are natural skylight, or an artificial ultra-violet source. It is necessary only to point the instrument in the direction from which a measurement is required.

In airborne applications, the incoming ultra-violet may be from skylight, in which case, the instrument receives input through an opening in the roof. The illustration in Figure 13 shows how an aircraft flying beneath an SO_2 plume can measure total SO_2 burden, in the path assuming the plume has finite dimensions. If the depth of the plume is known, the average concentration of the plume may be calculated. Another application available is through the use of a closed path system using mirrors on the perimeter of the aircraft as shown in Figure 14. In this mode, the aircraft flies within the plume and measures the SO_2 content

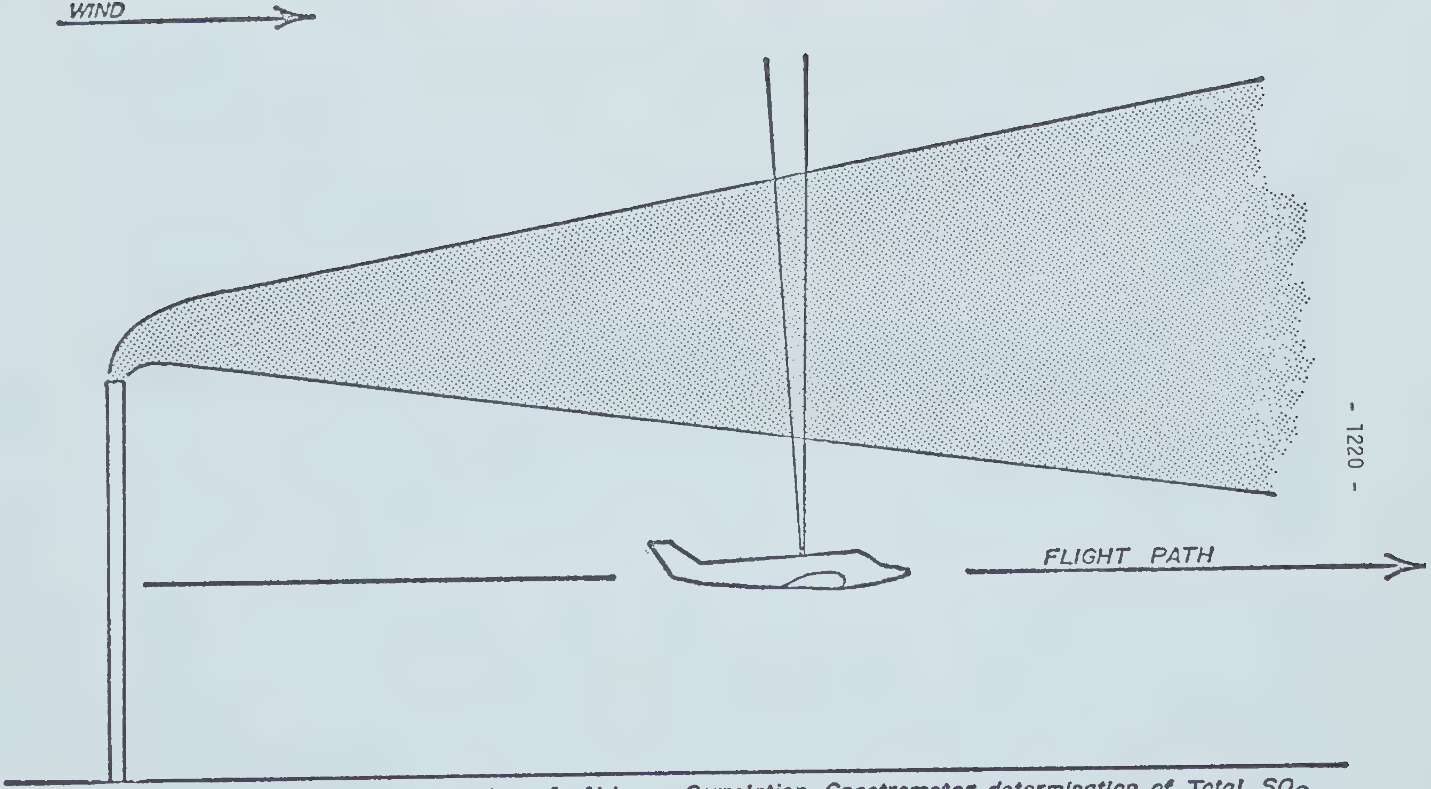


FIGURE 13. Idealized illustration of Airborne Correlation Spectrometer determination of Total SO_2 burden in plume using ambient light.

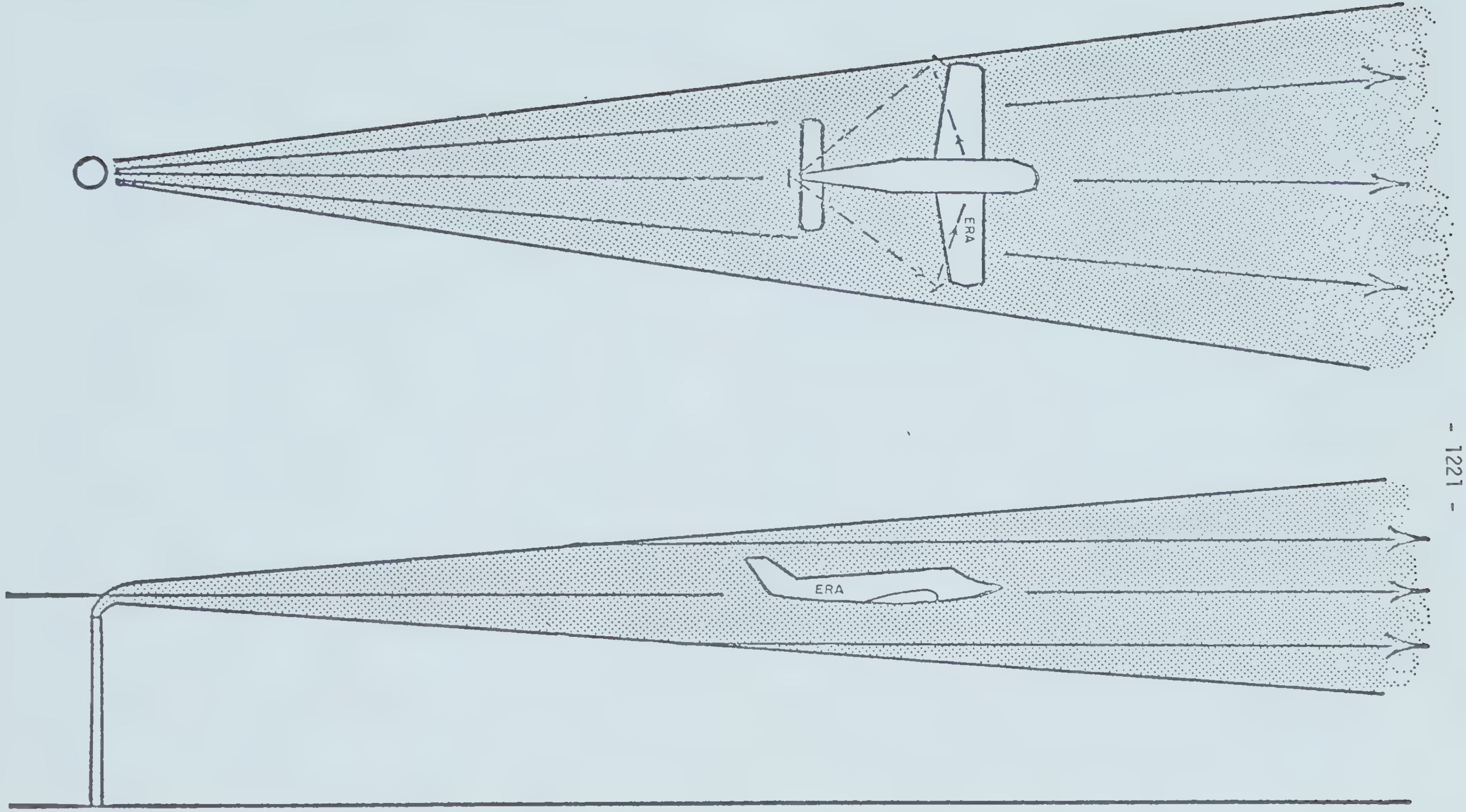


FIGURE 14. Idealized illustration of Airborne Correlation Spectrometer determination of SO_2 plume profile using closed circuit light system.

at that position. Yet another application requires that the instrument obtain the ultra-violet from below the aircraft through the floor. In this case, the instrument looks down on the plume from above. All three modes of operation are useful depending on data required and terrain. Obviously there are constraints against low flying aircraft due to buildings, surface roughness, etc. So the method of data acquisition must be used with judgment.

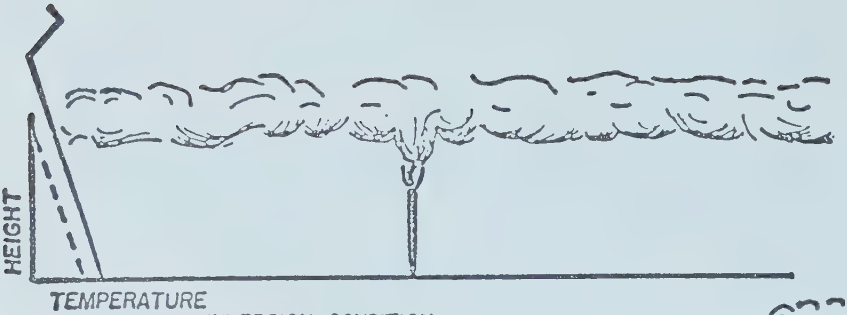
This technique produces real-time measurements of absolute SO_2 (and NO_2) concentrations in effluent plumes. The method provides data that fills one of the prime requirements for environmental management. Vis: it is necessary to know where the irritant is before any plan of control or management can be adopted.

Plume modeling techniques are widely employed in industry to estimate plume behavior. The basic assumptions inherent in such techniques may lead to serious discrepancies between predicted and actual plume position and effluent concentrations. Models can become quite sophisticated,but many of them suffer due to the basic assumption that atmospheric diffusion produces a gaussian distribution of effluents. Nature can be singularly non-gaussian due to wind shear, unusual temperature lapse conditions and surface roughness elements. Too little actual data exists on the actual behavior of plumes compared to that predicted by models. Until the advent of airborne methods and real-time air quality samplers such as the correlation spectrometer, such data was not obtainable.

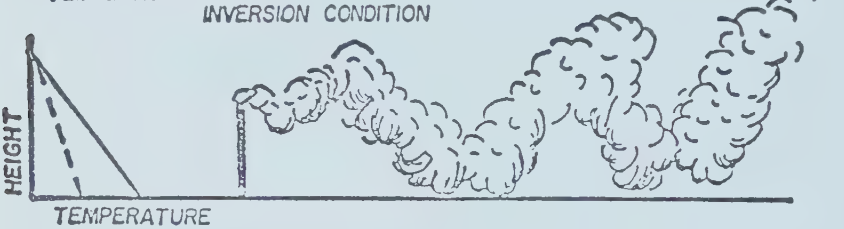
It is possible to describe plumes according to behavior under certain meteorological conditions. These somewhat idealized conditions are shown in Figures 15 and 16. Notice that temperature lapse rate is the only meteorological input into this classification and enormous variability is possible due to other factors such as surface roughness or temperature inhomogenieties. Further descriptions of these "ideal" situations are available in the literature.

III. SOME ASPECTS OF THE ENVIRONMENT OF THE OKOTOKS GAS-PLANT AREA

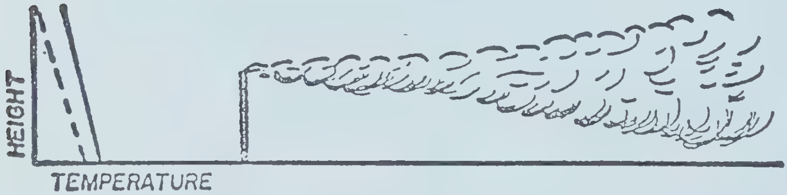
The Okotoks processing plant is located on a river terrace near the Sheep River, with the sulphur storage at a lower elevation, 300 yards to the south on the old flood plain of the river. Figure 17 is a telephoto view of the plant site from the hill crest on the north at about the 3,800 foot contour, looking over the plant, and to another hill on the south (middle, rightside of the photograph). Figure 18 is a view from the south hill, overlooking the plant site to the north hill from which the photo in Figure 17 was taken. Note that the terrain is somewhat undulating and has been turned mainly to agriculture. Note also that the top of the stack is at about the level of the north hill top.



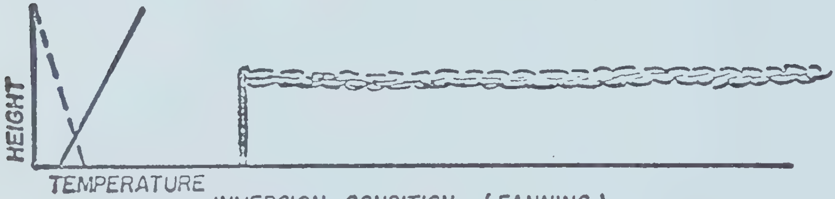
INVERSION CONDITION



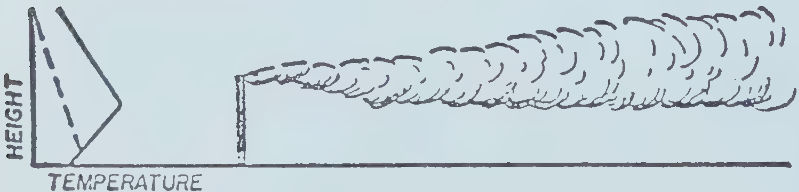
STRONG LAPSE CONDITION (LOOPING)



WEAK LAPSE CONDITION (CONING)

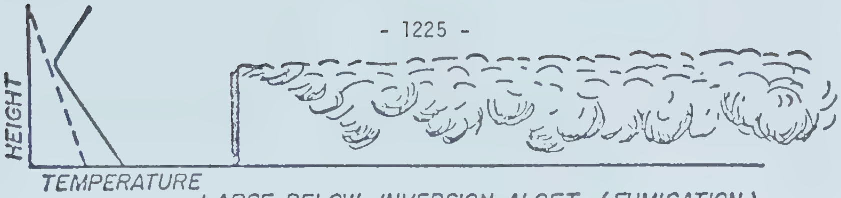


INVERSION CONDITION (FANNING)

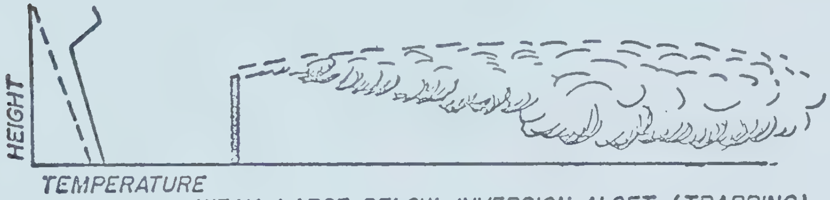


INVERSION BELOW, LAPSE ALOFT (LOFTING)

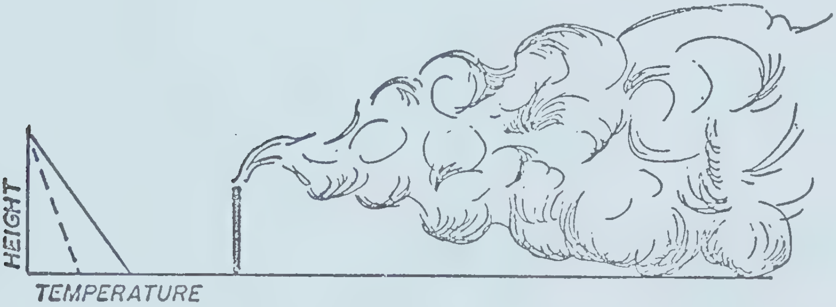
FIGURE 15. Idealized plume configurations under various meteorological conditions. Dotted and solid lines are adiabatic and existing lapse rates respectively.



LAPSE BELOW, INVERSION ALOFT (FUMIGATION)



WEAK LAPSE BELOW, INVERSION ALOFT (TRAPPING)



STRONG LAPSE, WELL DISPERSED PLUME, LIGHT WINDS.

FIGURE 16. *Idealized plume configurations under various meteorological conditions. Dotted and solid lines are adiabatic and existing lapse rates respectively.*

Three important aspects of the Okotoks gas-plant environment were studied. The soils, vegetation, and atmospheric factors were studied with a view to determining the degree of industrial encroachment, if any. In this study, ERA used several sensing methods as outlined in principle, in the previous section.

(a) Sulphation at the Surface:

ERA obtained total sulphation data which pertains to the period 1969 - 1971. These data are shown in Figures 19 to 31. Wind rose data are shown in Figure 19 which pertains to the entire period of record 1969 - 1971. Predominant winds are from the north and west quadrants. Note however that there is a substantial number of occurrences with south east winds. South east winds normally coincide with upslope synoptic conditions and possible plume trapping inversions. Sulphation data beginning at Figure 20 suggest that deposition occurs mainly in the winter season. This however, is only a trend since the deposition is variable. It is to be noted that surface sulphation is highest in the eastern half of the compass. Even though the collection cylinder placement may have biased the data, there is a trend to increased deposition under westerly and southerly flow. For example Figure 20 shows a predominently northerly wind flow with only light deposition to the south of the plant. Lighter westerlies produced widespread deposition to the east. Light southerly flow produced heavier deposition to the north possibly due to up-slope plume trapping inversions. Figure 23 shows the

WINDROSE 1969 - 1971

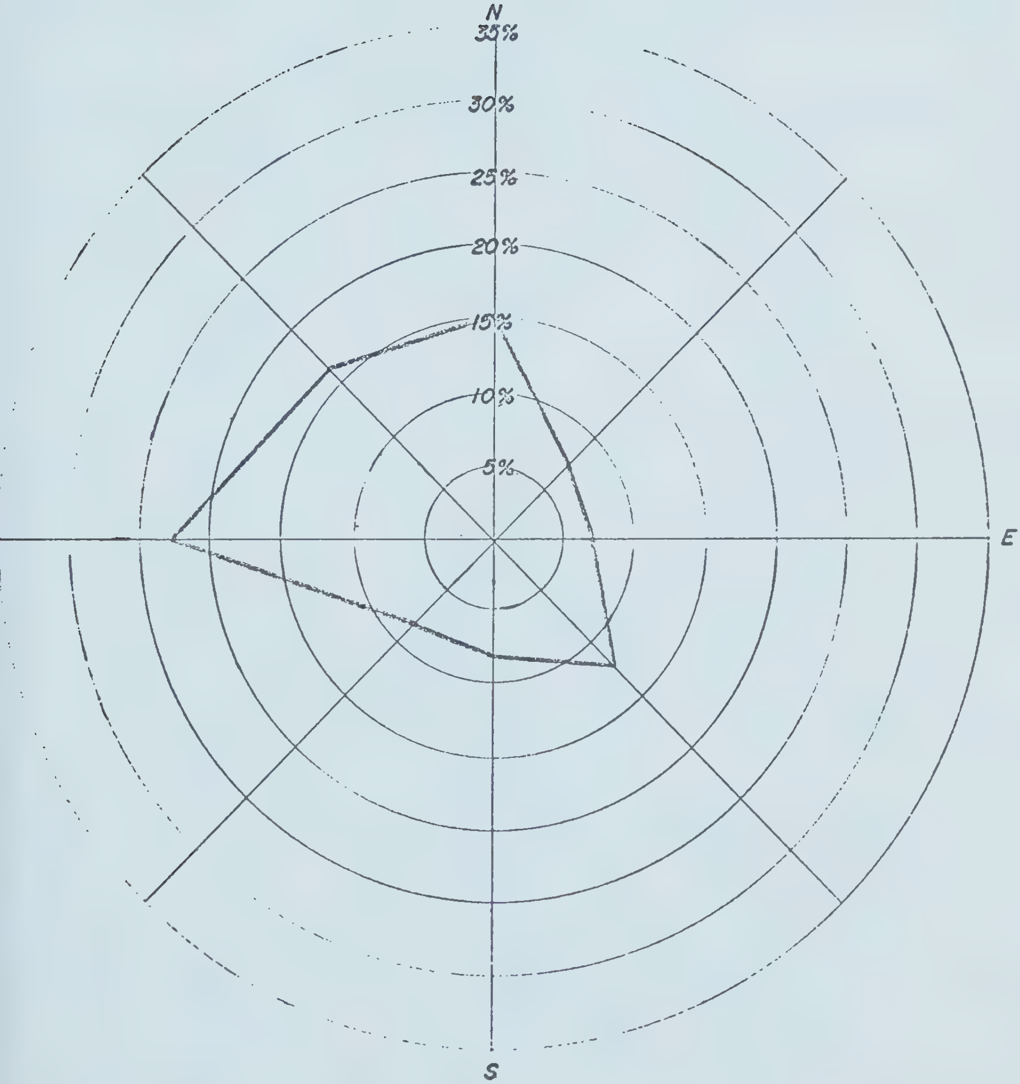
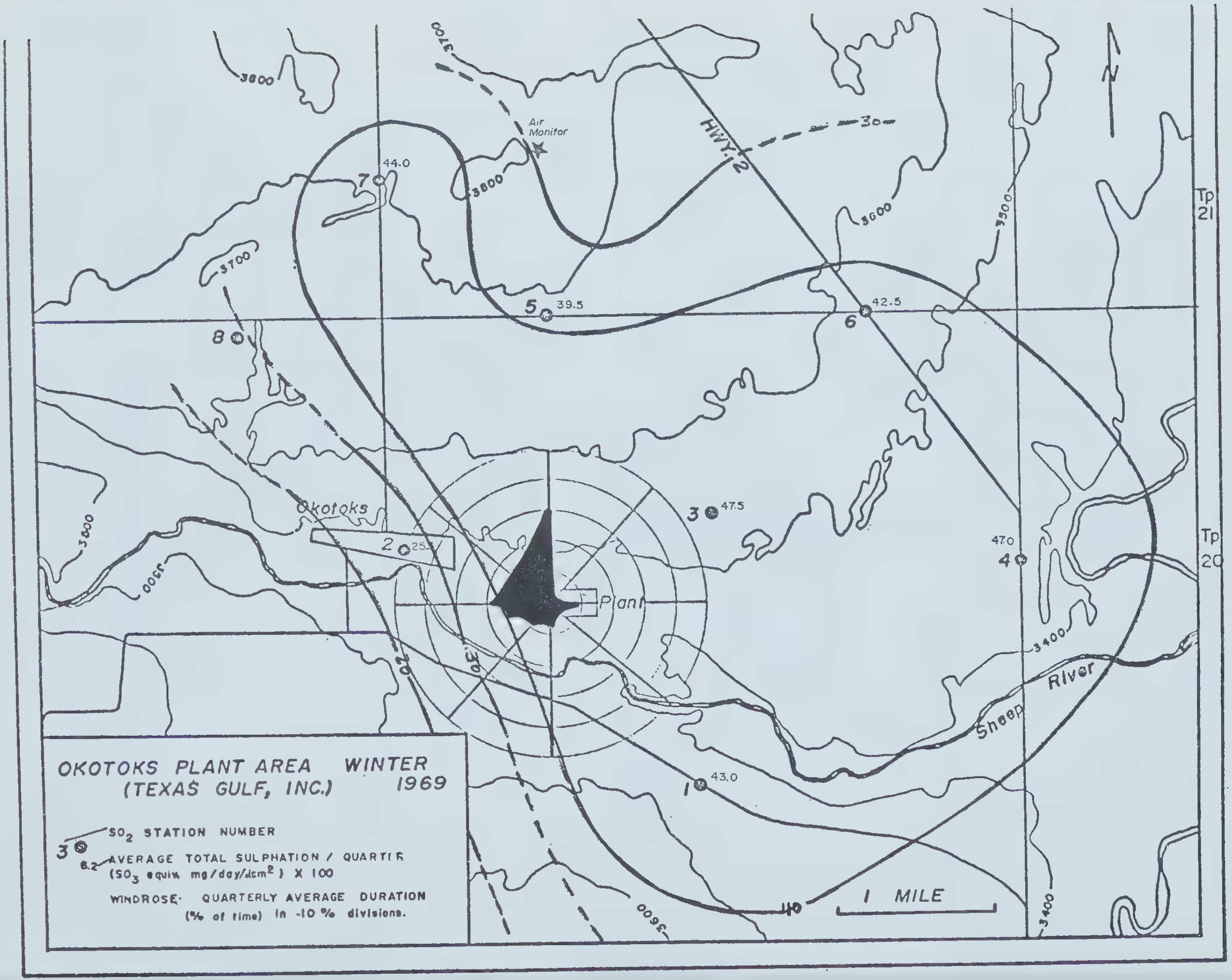


FIGURE 19. AVERAGE WIND DIRECTION DISTRIBUTION for OKOTOKS PLANT.



OKOTOKS PLANT AREA WINTER 1969
(TEXAS GULF, INC.)

3 ⊗ SO$_2$ STATION NUMBER
6.2 AVERAGE TOTAL SULPHATION / QUARTER
(SO$_3$ equiv. mg/day/dcm^2) X 100
WINDROSE: QUARTERLY AVERAGE DURATION
(% of time) in -10 % divisions.

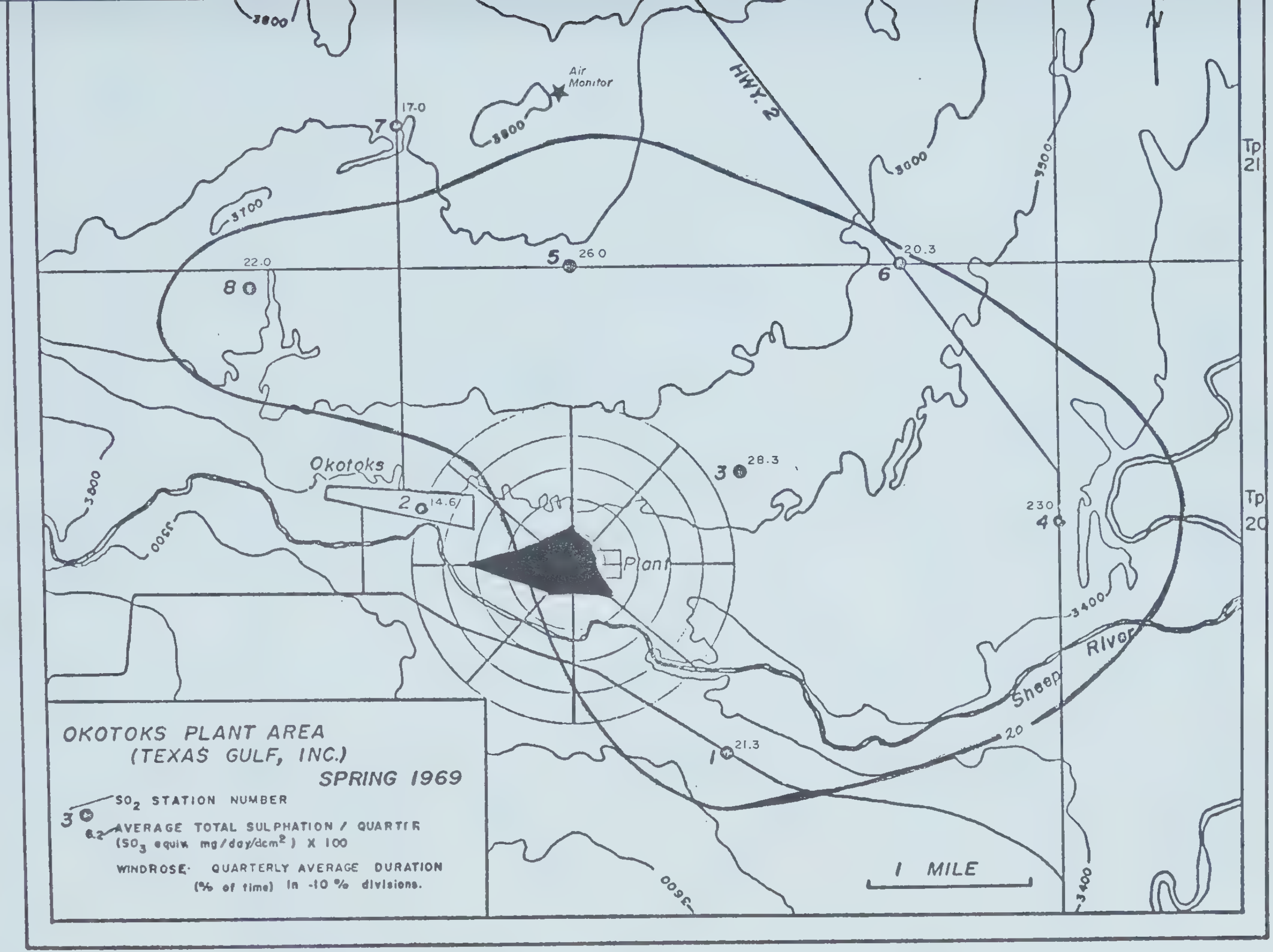
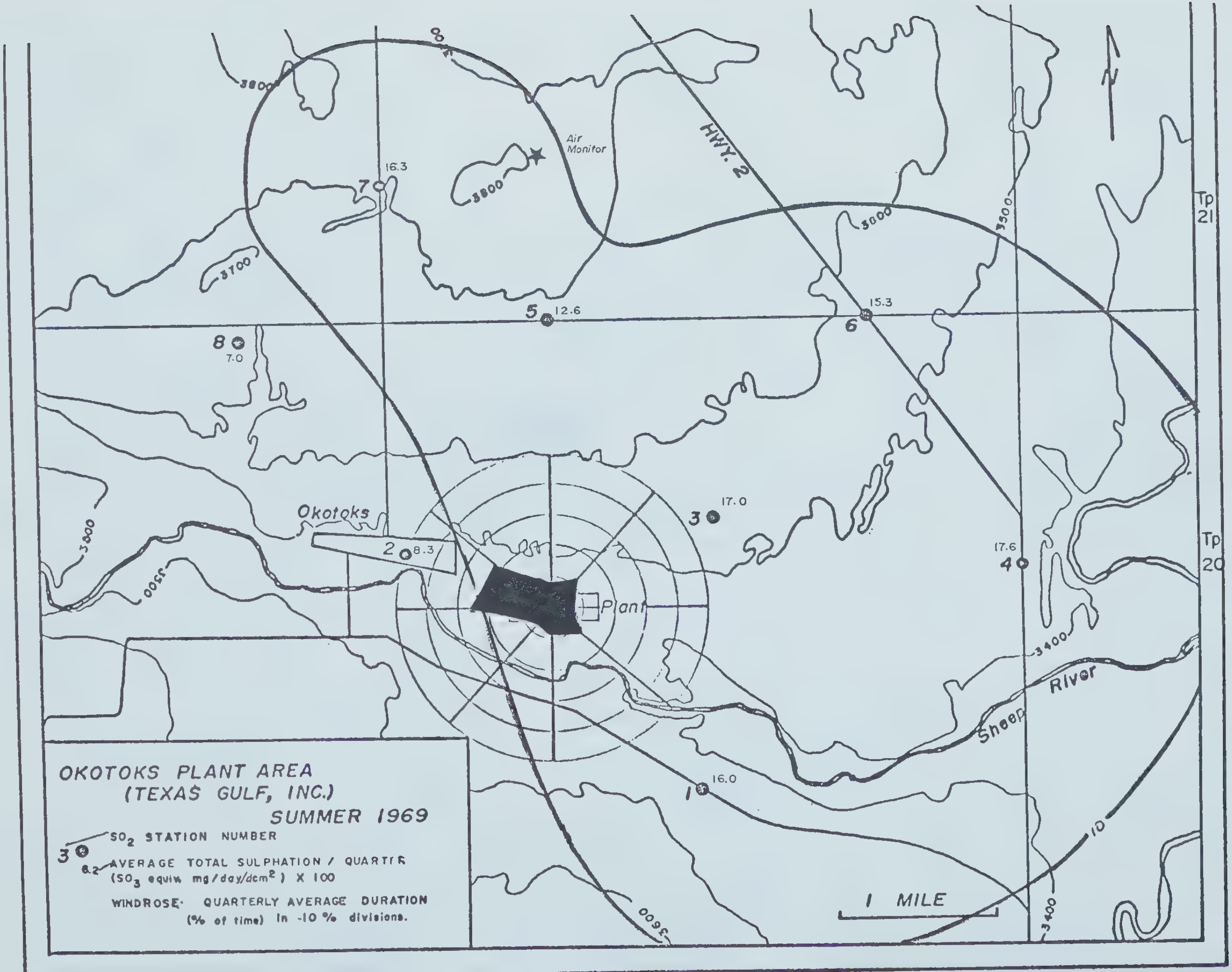


FIGURE 21. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. SPRING 1969.



OKOTOKS PLANT AREA
(TEXAS GULF, INC.)
SUMMER 1969

3 — SO_2 STATION NUMBER
8.2 — AVERAGE TOTAL SULPHATION / QUARTER (SO_3 equiv. mg/day/dcm^2) X 100

WINDROSE: QUARTERLY AVERAGE DURATION (% of time) in -10 % divisions.

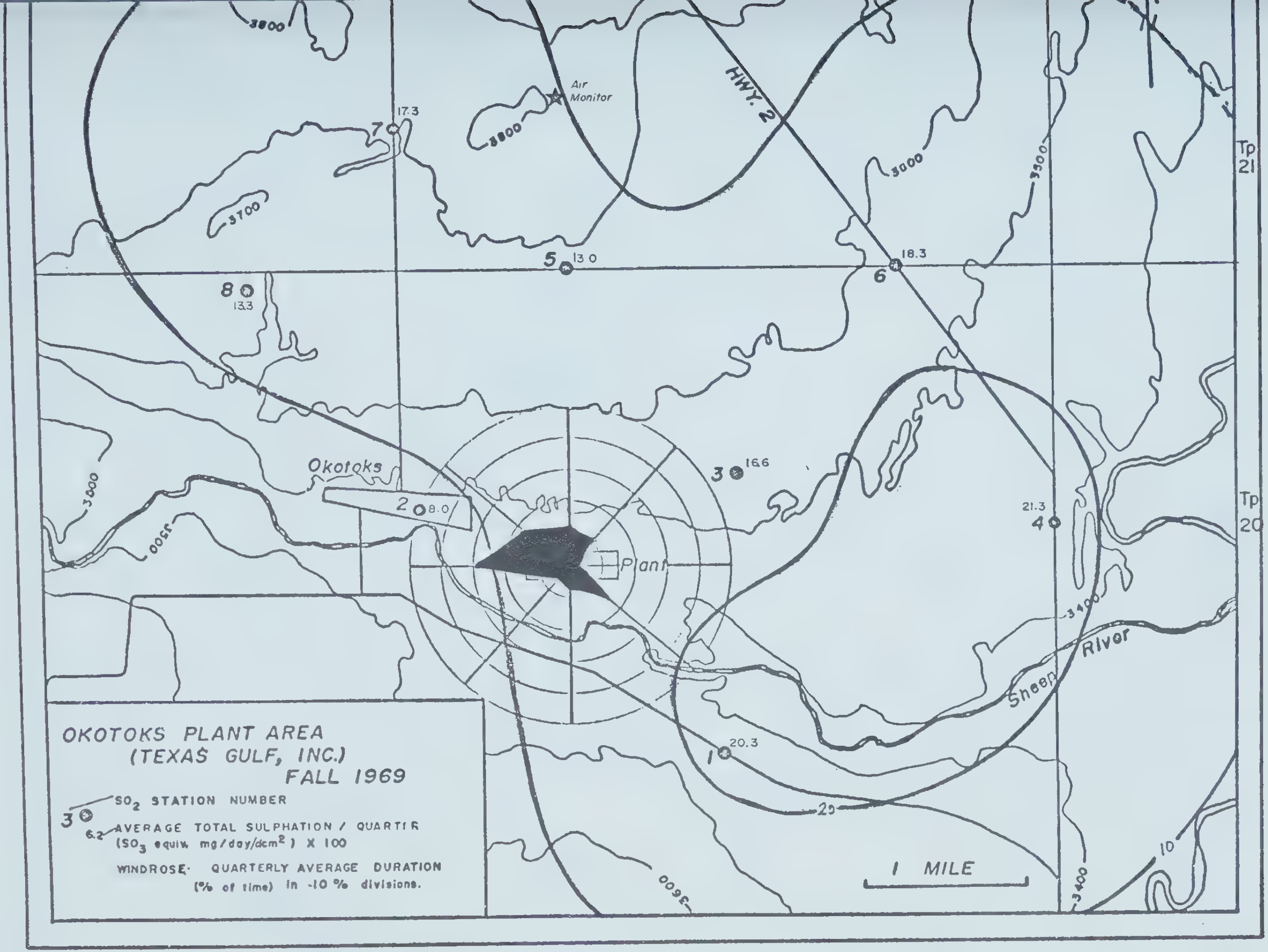
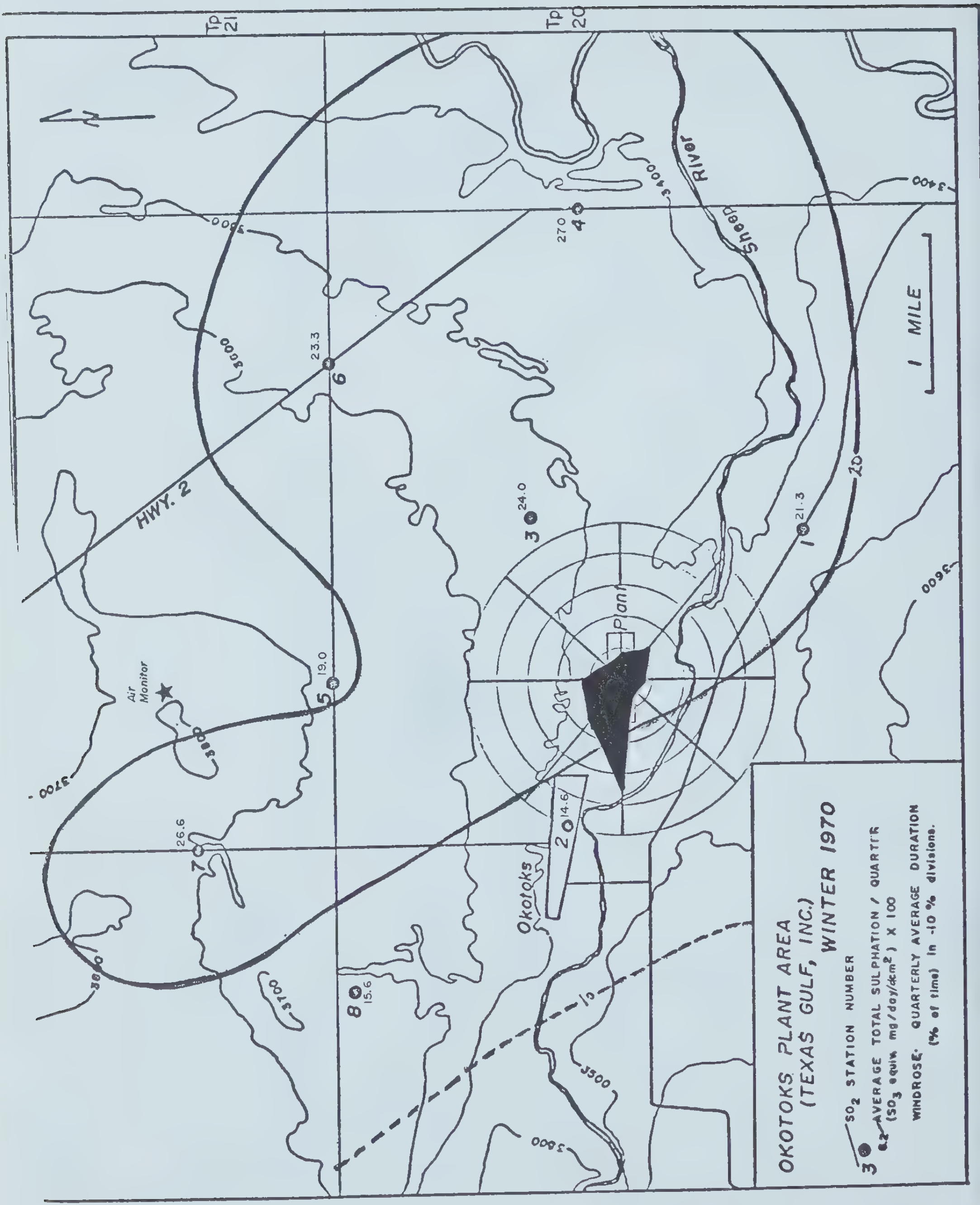


FIGURE 23. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. FALL 1969.


OKOTOKS PLANT AREA
(TEXAS GULF, INC.)
WINTER 1970
3 SO$_2$ STATION NUMBER
6.2 AVERAGE TOTAL SULPHATION / QUARTER
(SO$_3$ equiv. mg/day/dcm^2) X 100
WINDROSE: QUARTERLY AVERAGE DURATION
(% of time) in 10 % divisions.
1 MILE
Tp 21
Tp 20
HWY. 2
Sheep River
Plant
Okotoks
Air Monitor
1 21.3
2 14.6
3 24.0
4 27.0
5 19.0
6 23.3
7 26.6
8 15.6
10
20
3400
3500
3600
3700
3800
3900
4000

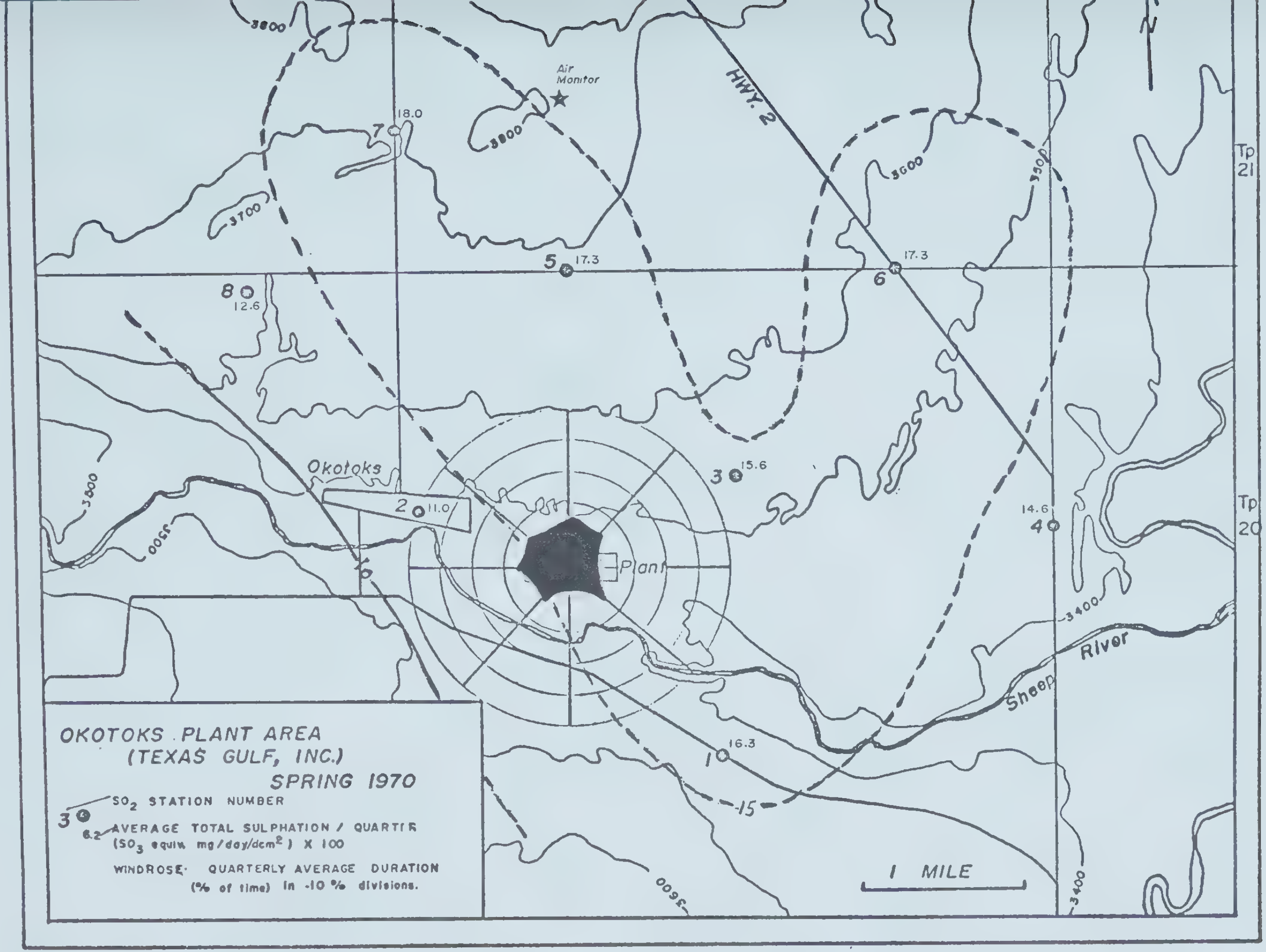
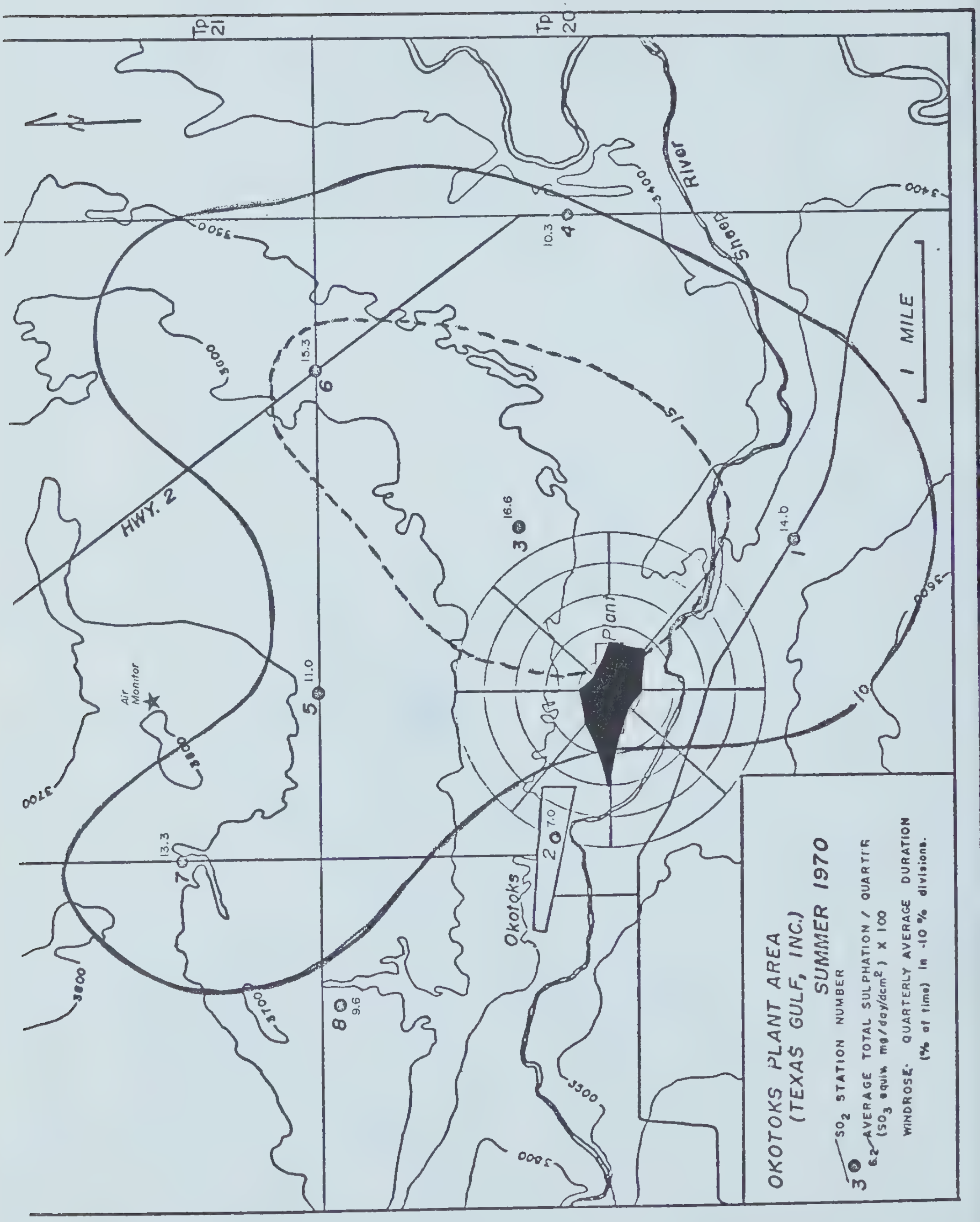


FIGURE 25. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. SPRING 1970.


OKOTOKS PLANT AREA
(TEXAS GULF, INC.)
SUMMER 1970
3 SO2 STATION NUMBER
6.2 AVERAGE TOTAL SULPHATION / QUARTER (SO_3 equiv. mg/day/dcm²) x 100
WINDROSE: QUARTERLY AVERAGE DURATION (% of time) in -10 % divisions.
1 MILE
Tp 21
Tp 20
HWY. 2
Sheep River
Okotoks
Plant
Air Monitor
1 14.0
2 7.0
3 16.6
4 10.3
5 11.0
6 15.3
7 13.3
8 9.6
10
15
3400
3500
3600
3700
3800

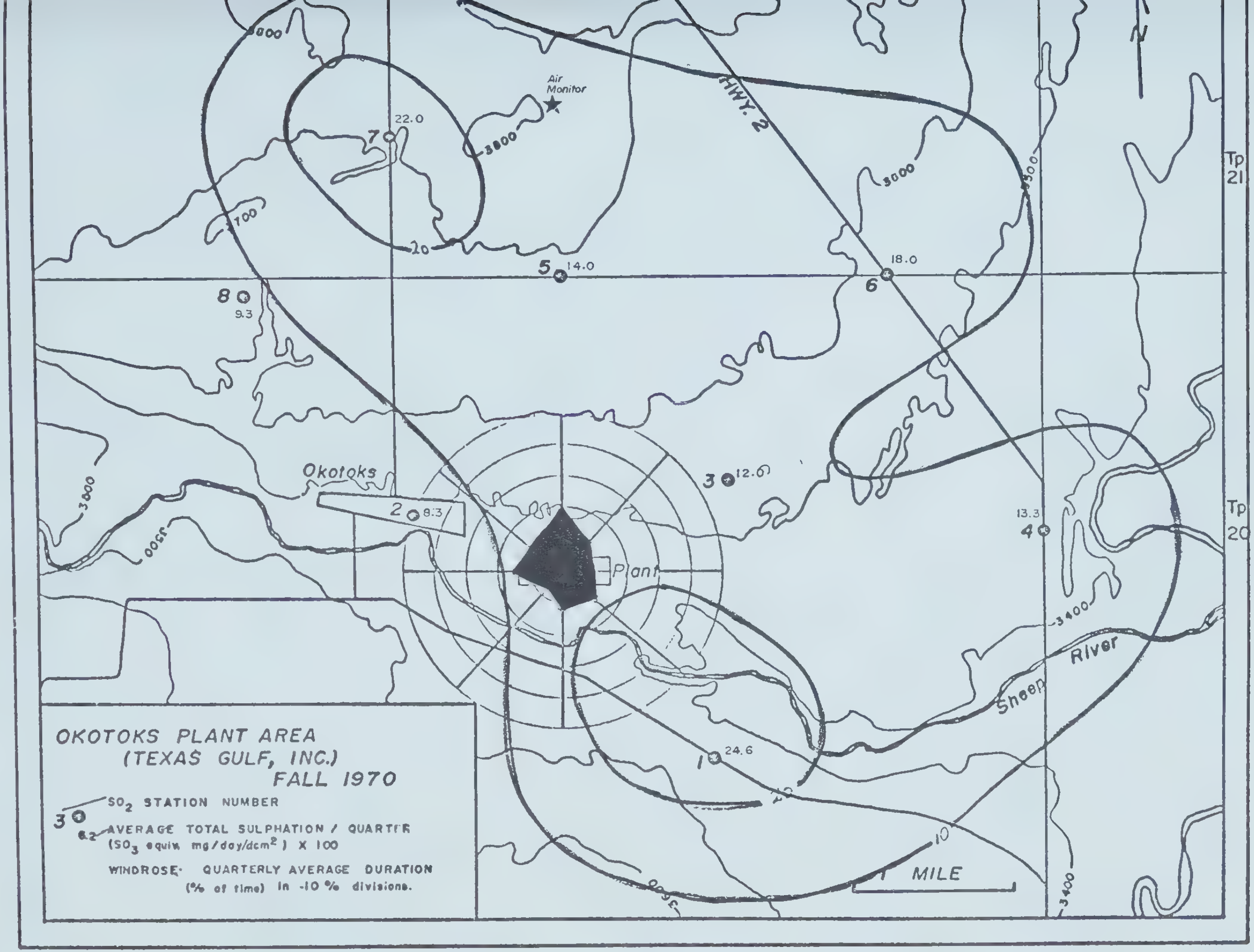
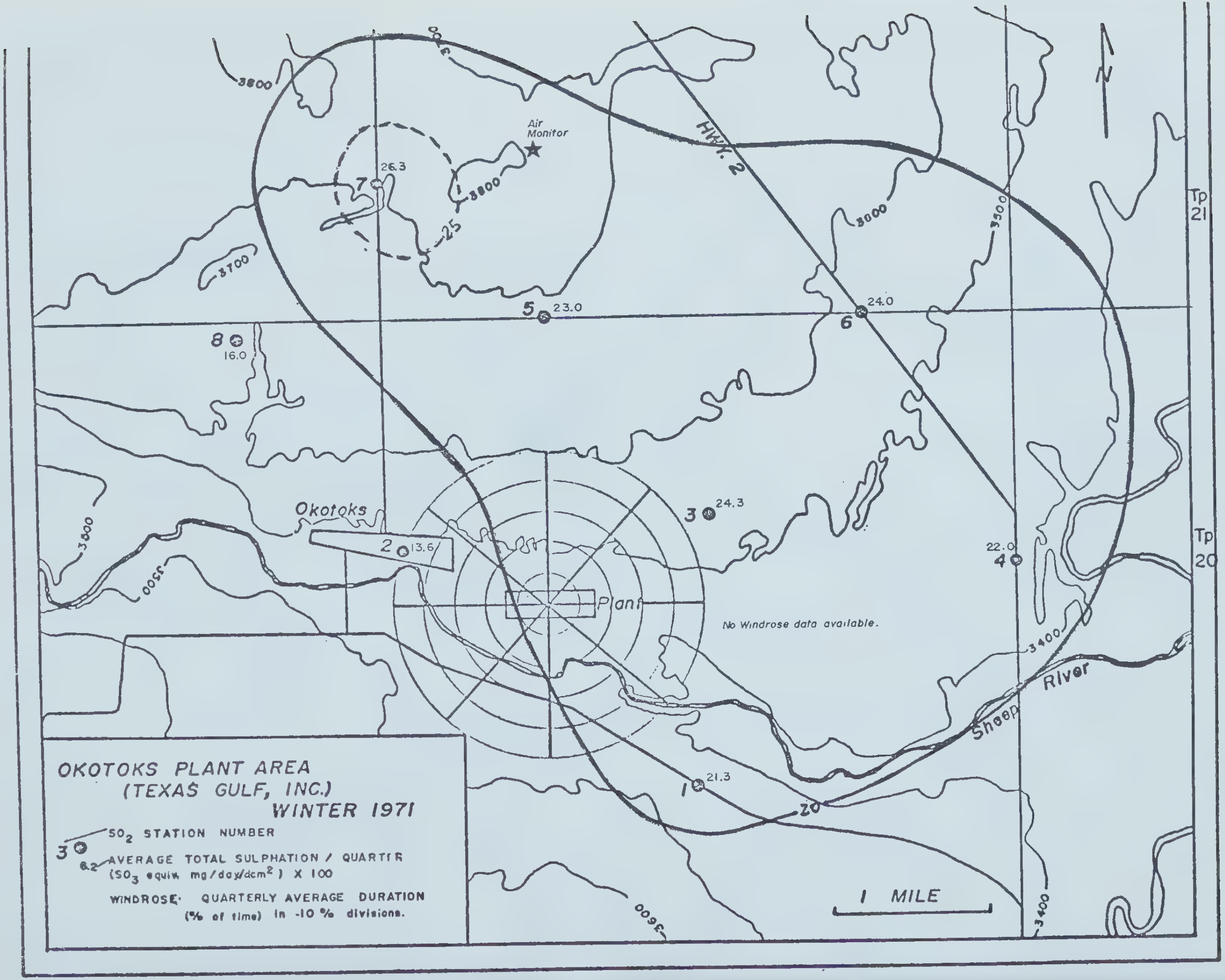


FIGURE 27. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. FALL 1970.



OKOTOKS PLANT AREA
(TEXAS GULF, INC.)
WINTER 1971

3 SO$_2$ STATION NUMBER
6.2 AVERAGE TOTAL SULPHATION / QUARTER
(SO_3 equiv. mg/day/dcm^2) X 100

WINDROSE: QUARTERLY AVERAGE DURATION
(% of time) in -10 % divisions.

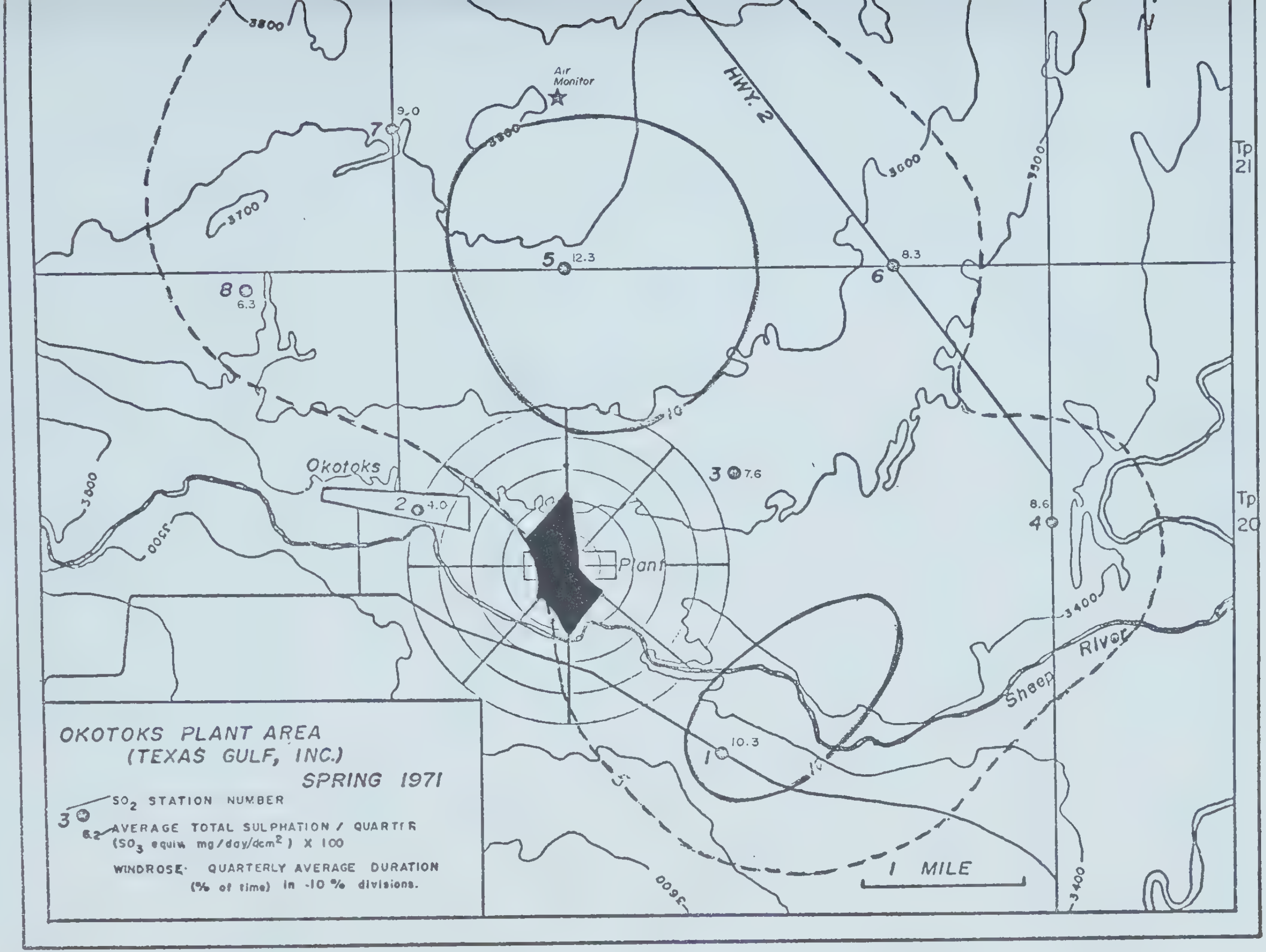
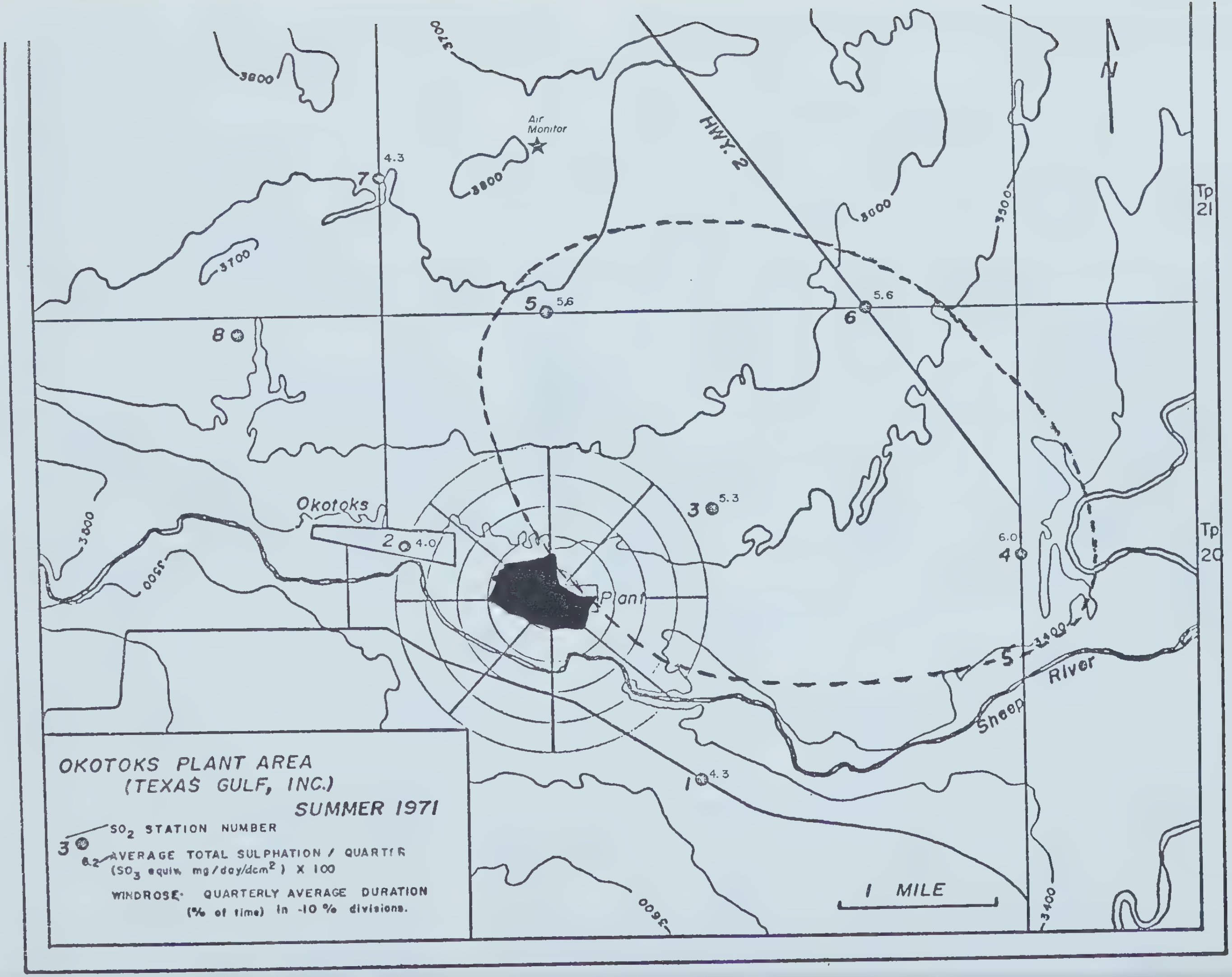


FIGURE 29. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. SPRING 1971.



OKOTOKS PLANT AREA
(TEXAS GULF, INC.)
SUMMER 1971

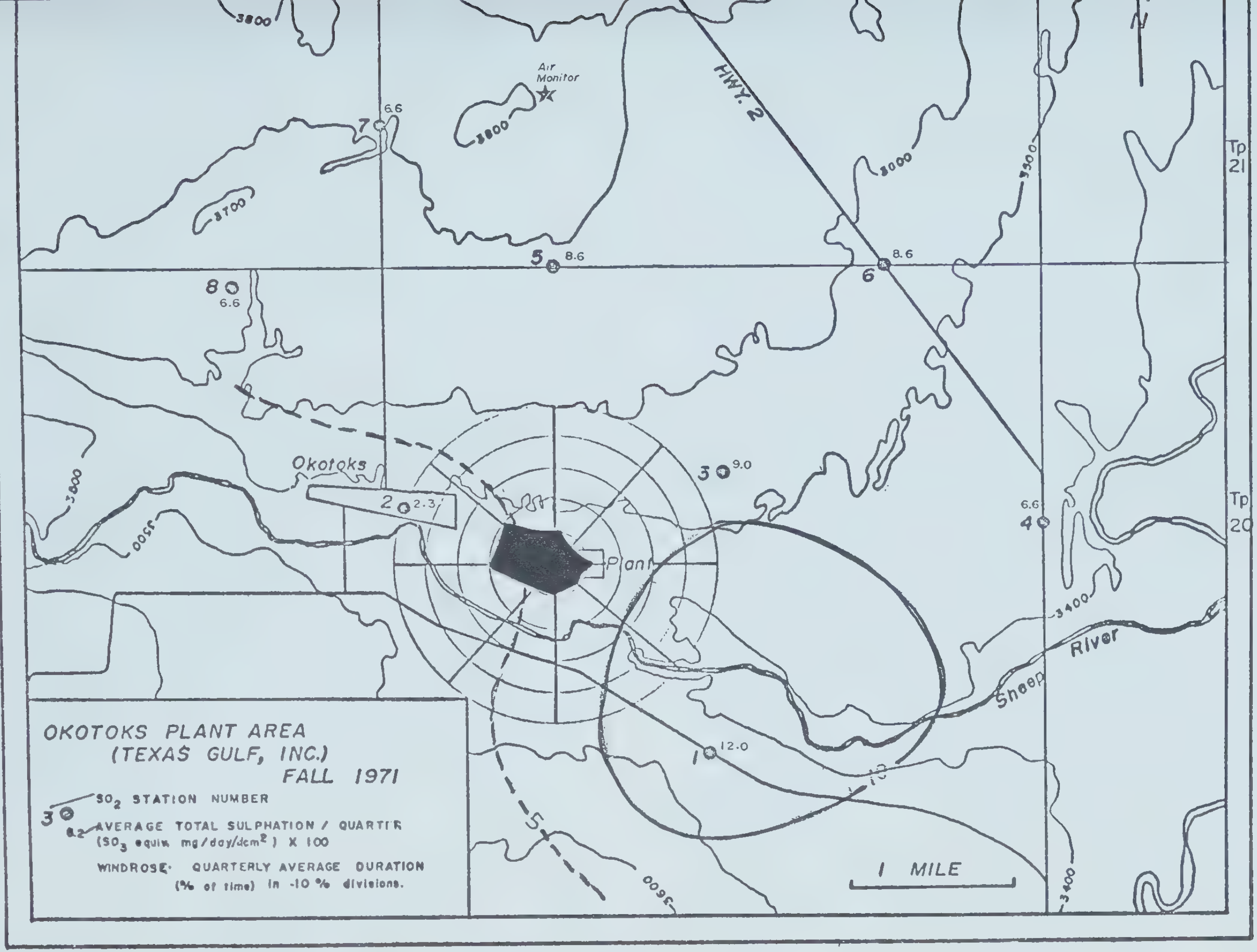


FIGURE 31. OKOTOKS PLANT - QUARTERLY TOTAL SULPHATION & WINDROSE. *FALL 1971.*

same trend with heaviest concentrations of total sulphation to the east of the plant. Figures 27 and 28 suggests a large number of southerly winds and deposition on the hillcrest to the north. The lightest deposition quarter occurred during the summer of 1971. In general, deposition of sulphur compounds occurs in conformity with the prevailing wind patterns, that is, with highest surface concentrations to the east. It also appears that southerly winds cause deposition on the north hill inspite of the lower incidence of such winds. These data may be strongly biased by the distribution of the collection cylinders. It cannot be concluded from these data above, that other sources contribute to the surface sulphation, even though it is a strong possibility. This point will be discussed later.

A continuous air monitoring station was in operation in the OKOTOKS plant area from December 1971 to April 1972, and was located about three miles NNW of the plant site near the north hill crest at 3800 feet elevation, (Figure 20). Instrumentation measured sulphur dioxide and wind speed and direction. SO_2 concentrations averaged 0.00324 ppm over the period. Peak concentrations of SO_2 occurred when winds were from the northern sector, but only 34 readings above 0.10 ppm occurred during the 3½ month period of record. The maximum 30-minute average for the period was 0.275 ppm.

A comparison of wind direction and sulphation concentrations indicates that maximum concentrations occur during north, south and southwest flow. This suggests that the sulphur dioxide originates from sources to the north and southwest, as well as from the OKOTOKS plant.

(b) Soil and Vegetation Survey:

A field survey was conducted in the OKOTOKS area to determine by ground sampling, the degree of effect of sulphur compounds on the environment. Soil samples were collected as outlined under II. Vegetation surveys were carried out by visually inspecting critical areas as will be outlined below.

Samples were obtained from the A_1,A_2 and B_1 soil horizons and analyzed for pH, conductivity, total sulphates, and free lime. The sampling sites and analyses of the A_1 horizon are shown in Figures 32 and 33. The complete analysis is shown in Table 1. Note that pH effects are very local but significant. Where pH

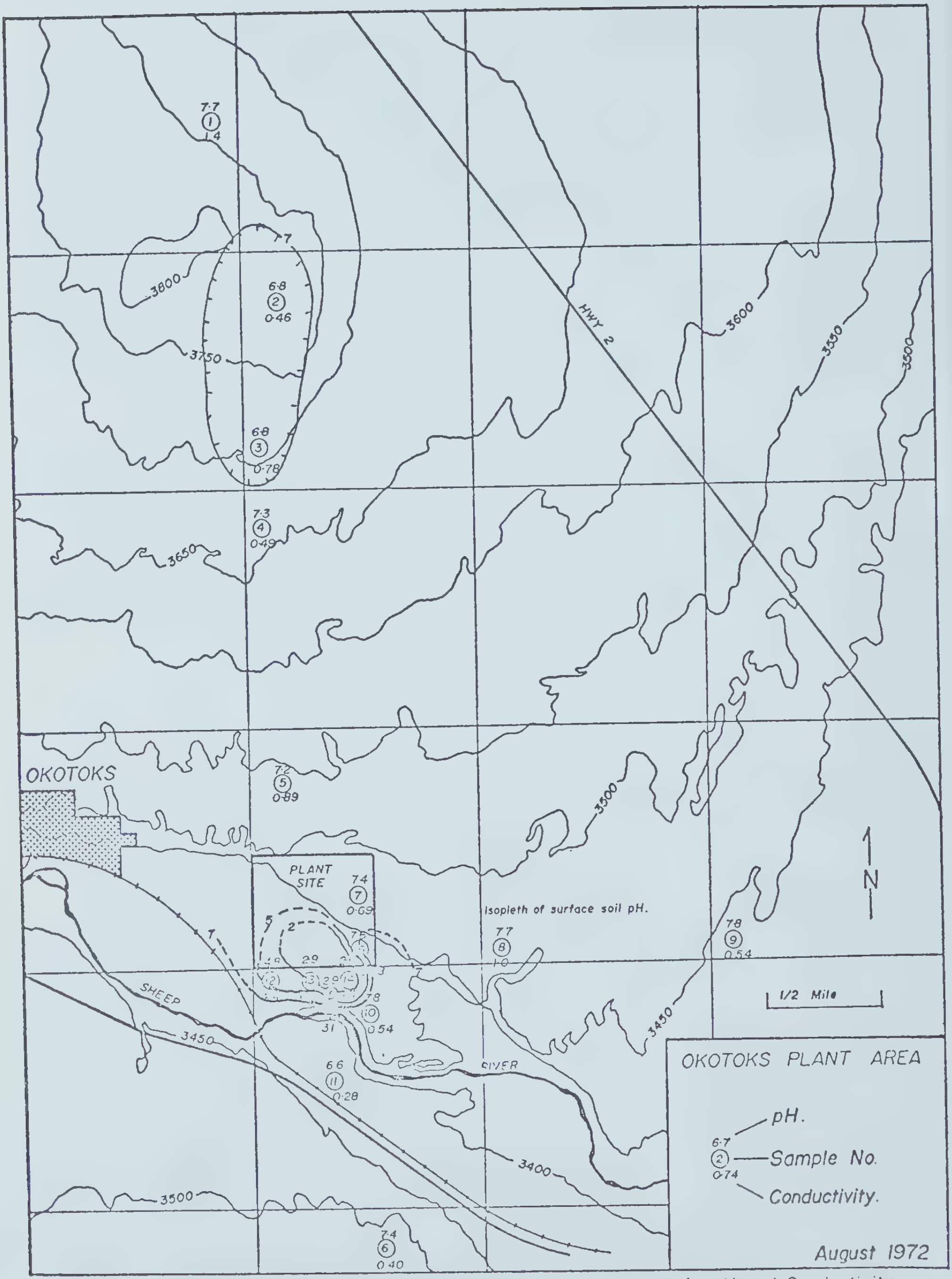
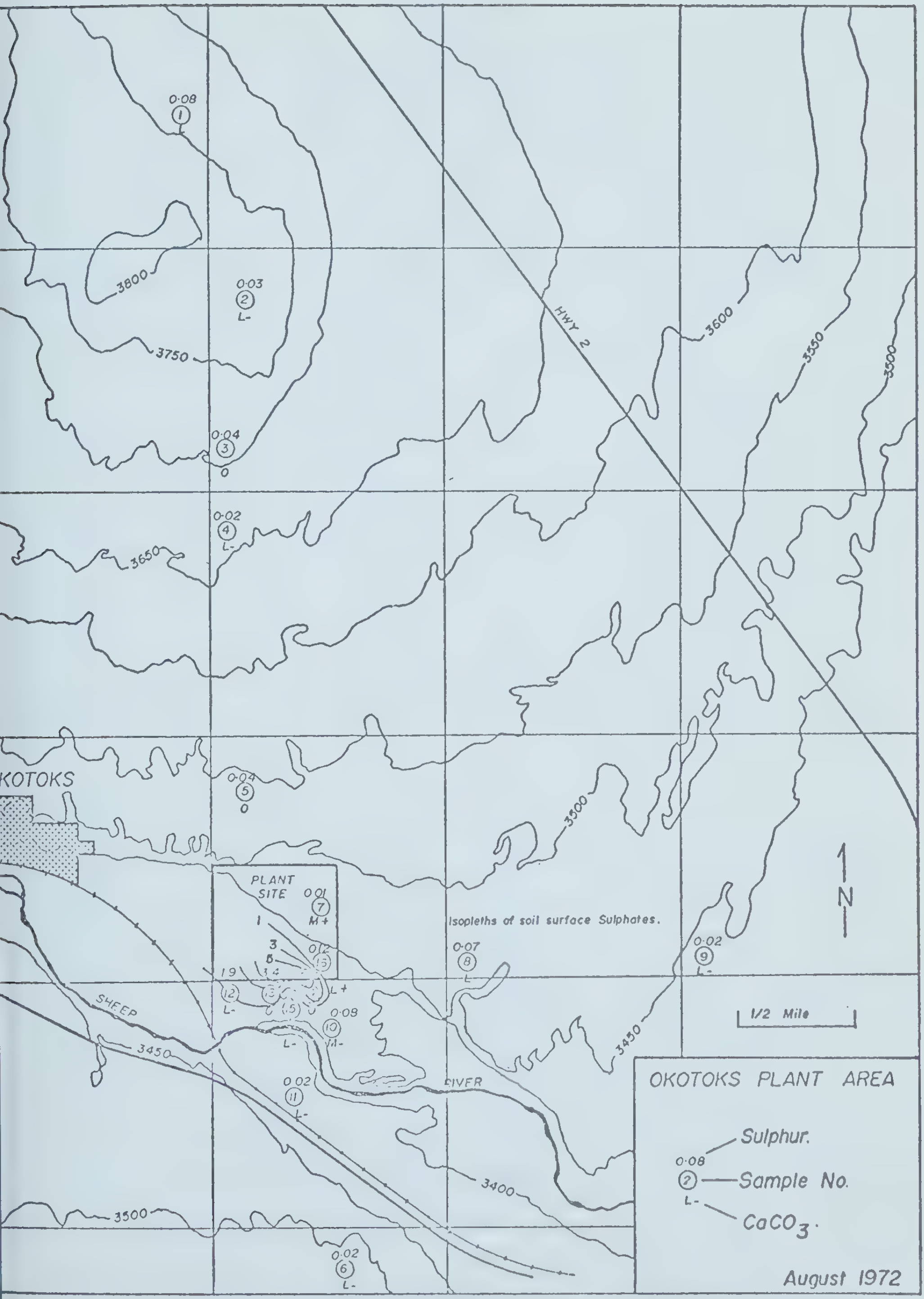


FIGURE 32. OKOTOKS SOIL SAMPLE LOCATIONS, (Al Horizon only). pH and Conductivity.



GURE 33. OKOTOKS SOIL SAMPLE LOCATIONS, (Al Horizon only). Sulphur and $CaCO_3$.

Table I

Soil Analysis of Samples From Okotoks Gas - Plant Area

(August 1972)

Sample		pH	Conductivity	S(%)	$CaCO_3$
Site 1	A1	7.7	1.4	0.08	L
	A2	8.0	1.1	0.05	L
	B1	8.4	0.50	0.01	L
Site 2	A1	6.8	0.46	0.03	L-
	A2	6.9	0.35	0.02	L-
	B1	7.1	0.22	0.01	0
Site 3	A1	6.8	0.78	0.04	0
	A2	7.0	0.38	0.01	L-
	B1	7.3	0.26	0.005	L-
Site 4	A1	7.3	0.49	0.02	L-
	A2	7.2	0.54	0.05	L-
	B1	7.6	0.32	0.03	L-
Site 5	A1	7.2	0.89	0.04	0
	A2	7.5	0.84	0.03	0
	B1	8.2	0.51	ND	M+
Site 6	A1	7.4	0.40	0.02	L-
	A2	7.5	0.56	0.01	L
	B1	7.8	0.43	ND	L-
Site 7*	A1	7.4	0.69	0.01	M+
	A2	7.6	0.54	0.02	M
	B1	7.8	0.56	0.02	H
Site 8	A1	7.7	1.0	0.07	L
	A2	7.5	0.53	0.03	L-
	B1	7.9	0.60	0.02	H-
Site 9	A1	7.8	0.54	0.02	L-
	A2	7.6	0.50	0.01	L-
	B1	u.8	0.48	0.01	M-
Site 10*	A1	7.8	0.54	0.08	M-
	A2	8.2	0.42	0.06	M-
	B1	8.2	0.63	0.06	H
Site 11	A1	6.6	0.28	0.02	L-
	A2	6.6	0.29	0.02	L-
	B1	7.5	0.40	0.02	L-
Site 12*	A1	4.8	4.4	1.9	L-
	A2	7.5	4.2	0.28	M-
	B1	7.8	3.2	0.13	H
Site 13*	A1	2.9	6.0	3.4	0
	A2	7.3	4.4	0.26	L
	B1	7.6	4.0	0.19	M+

insufficient to have any effect on crop growth. (Crop growth was examined for possible SO_2 stress symptoms and the results were negative. (See later sections). Figure 33 presents isopleths of soil surface horizon sulphates and this information supports the pH data in Figure 32.

It is interesting to compare these data with those obtained by McAllister in August 1970. Several of the sites of ERA in 1972 were purposely duplicated for a time series comparison. ERA sites 12, 13, 14, and 16, were in virtually the same location as McAllister's sites 1, 2, 3, and 4. The comparisons of the soil A_1 horizon are shown in Table 2. A drop in pH has occurred at the comparison sites near the sulphur storage in the interveening two years. Site ERA - 16 has not been similarly affected.

It should be pointed out that the buffering properties of soils cause the above time change patterns. Under the above conditions, the natural buffering capacity would normally maintain a relatively high and relatively stable pH level for a number of years till the buffering limits have been exceeded. This would then be followed by a period of rapid decrease in surface pH to a new stable lower level. Amelioration of such a condition involves reduction or cessation of sulphur compound intrusion, deep tillage and planting of low pH tolerant grasses, or lime treatment. Lime treatments cannot be expected to repeatedly relieve the low pH situation however, unless the sulphur compound

Table 2

Comparison of A_1 Soil Horizon pH, and Sulphates From 1970 (McAllister) and 1972 (ERA) Near The Okotoks Gas - Plant

Site		pH		Sulphates	
ERA	McAllister	ERA	McAllister	ERA	McAllister
12	3	4.8	7.1	1.9%	M+
13	2	2.9	6.4	3.4%	H-
14	1	2.6	8.0	6.9%	ND*
16	4	7.6	6.5	0.12%	H

* Not Determined

intrusion stops.

Without liming, and without sulphur dusting, the soil would return to its former pH, but this is a very slow process. Return to normal pH through liming is a rapid process (one season). But unless the sulphur deposition stops, the pH will again begin to lower following each application of lime.

On such very small areas as are affected by sulphur storage areas, crop production degradation is certainly not the issue. Establishment of vegetation is important however, and this can be done without involving the repeated process of applying lime. Many species of grass are adaptable to such pH levels and may be planted on affected areas with excellent results.

At OKOTOKS, the area in question is immediately south of the sulphur storage and is approximately site ERA - 13. Thistles and grass with generally patchy growth are evident over a restricted area. The tenant grazes stock in this pasture and states that his animals show no harmful effects due to the proximity to the sulphur storage. A vegetable garden produced by the same person in a nearby plot, but out of the low pH area, is very prolific.

Poplar trees in a hedge adjacent to the sulphur vat are generally affected. *Figure 34 is a close-up view of Populus leaves moderately affected by sulphur dust. Some invasion by leaf miner insects is also evident. Meristem leaves are most seriously affected. Figure 35 is a laboratory photo of an OKOTOKS sample of Balsam poplar leaves equally affected by leaf miner insects and sulphur dust. Insect invasions often mimic SO_2 effluent effects. (Samples were obtained from trees adjacent to the sulphur vat).

Data collected from OKOTOKS and other gas plants establishes that the main causative factor in lowered soil pH, and other effects, is sulphur dust. Data also points out that dust settling rate is fairly high, which results in the very local effects noticed here.

Another area of concern in connection with sulphur storage is the possible effect of other stock pile effluents, if they are permitted to reach natural water systems. Such a situation is possible if spillage of sulphur outside the storage area has occurred, or where other effluents such as rain water surplus and run-off has reached a natural course. Figures 36 and 37 show the progressive improvement in conditions of a stream near the OKOTOKS sulphur vats in mid-August 1972 from near the storage area (Figure 36) to near the Sheep River in Figure 37. Conditions 900 yards from the sulphur area as shown were such that no degradation was evident.

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* See "List of Figures" as outlined at the beginning of this submission.

Analysis of water effluent entering this streamlet near the sulphur vats indicated that water conditions were well within Department of Health limits, except for odor which was higher than limits. (See Table 3). It should be pointed out that odor tests are highly qualitative and depend on many variable human factors. It is not known how much reliance should be placed on such tests. Vegetation in natural stands was examined in many areas in the OKOTOKS gas plant area. Figure 38 is a stand of Populus tremuloides on the crest of the hill (elevation 3,800 feet) to the north. No positive indications of SO_2 stress were noted. The population in Figure 38 is a normal vigorous stand. Figure 39 is a typical example of Salix gauca that grows widely in the entire foothills area. The normal manner of this plant is for communities to have a large number of dead branches and trunks mixed with growing and green leafed plants. The bush dies back from the roots near the soil surface causing the entire trunk and branches to die back. New growth is from fresh succors at the crown near the soil surface. Hence stands of normal Salix gauca have a very "straggled" appearance. It should be remembered from previous pages that this area is where a lowered soil surface pH trend was noticed and where somewhat increased sulphation deposition occurred. Statistical techniques also predicted the possibility of high SO_2 concentrations at these places. Yet notwithstanding these observations, the vegetation on the entire hill showed no readily identifiable indications of SO_2 stress.

Table 3

Analysis of Water From Streamlet Flowing Into Sheep River Near Okotoks Gas - Plant (1972)

Analysis	Dept. Health Limit	April Analysis	May Analysis
Biochemical Oxygen demand (lb/day).	50	23	12
Threshold odor number	20	100	100
pH	6.5-9.5	8.5	9.1
Petroleum ether extractable compounds (mg/l)	15	14	<1
Nonfilterable residues (mg/l)	100	26	3

The south hill as seen in Figure 18 was also ground checked for similar symptoms. Figure 40 presents a view of a shelter hedge of young Poplar and Ash trees that displayed mild SO_2 symptoms at the time of observation in mid-August. A similar examination in early July was negative, suggesting that SO_2 as may have occurred up to early July was insufficient to visually affect the trees. Similar symptoms were noted as in Figure 41 which shows Populus tremuloids in a mild SO_2 stressed condition. This specimen and others similarly affected were located near the crest of the south hill to the west of the trees shown in Figure 40. Such symptoms were not noted in these trees, in early July.

These observations point to the seasonal aspects of environmental stressing. It is normally considered that plants will show greatest stress symptoms when the vegetation is most succulent and hence susceptible. There can be little doubt about this, provided sufficient irritant has come in contact with the plants to stress them when they are susceptible. No stress was observed during the succulent period (July), and yet did occur in mid-August when the vegetation is beginning to "harden" somewhat due to seasonal factors. Other observations by ERA have shown that when the stress agent (SO_2) is withdrawn, and provided the stress has been mild (short of causing death of the organism), the symptoms tend to disappear and the organism recovers.

These observations and those reported here from OKOTOKS point out that this type of SO_2 stress is not cumulative and that vegetation may be expected to recover.

The observation of SO_2 stress in August and not in July, also raises the strong possibility of SO_2 augmentations from other sources in addition to the OKOTOKS gas plant. It has been noted that SO_2 stress symptoms in vegetation are strongest on the side of the hill slope facing the source. Since stress was noted on the south and not on the north hill, the possible contribution of municipal Calgary and other nearby sources cannot be overlooked.

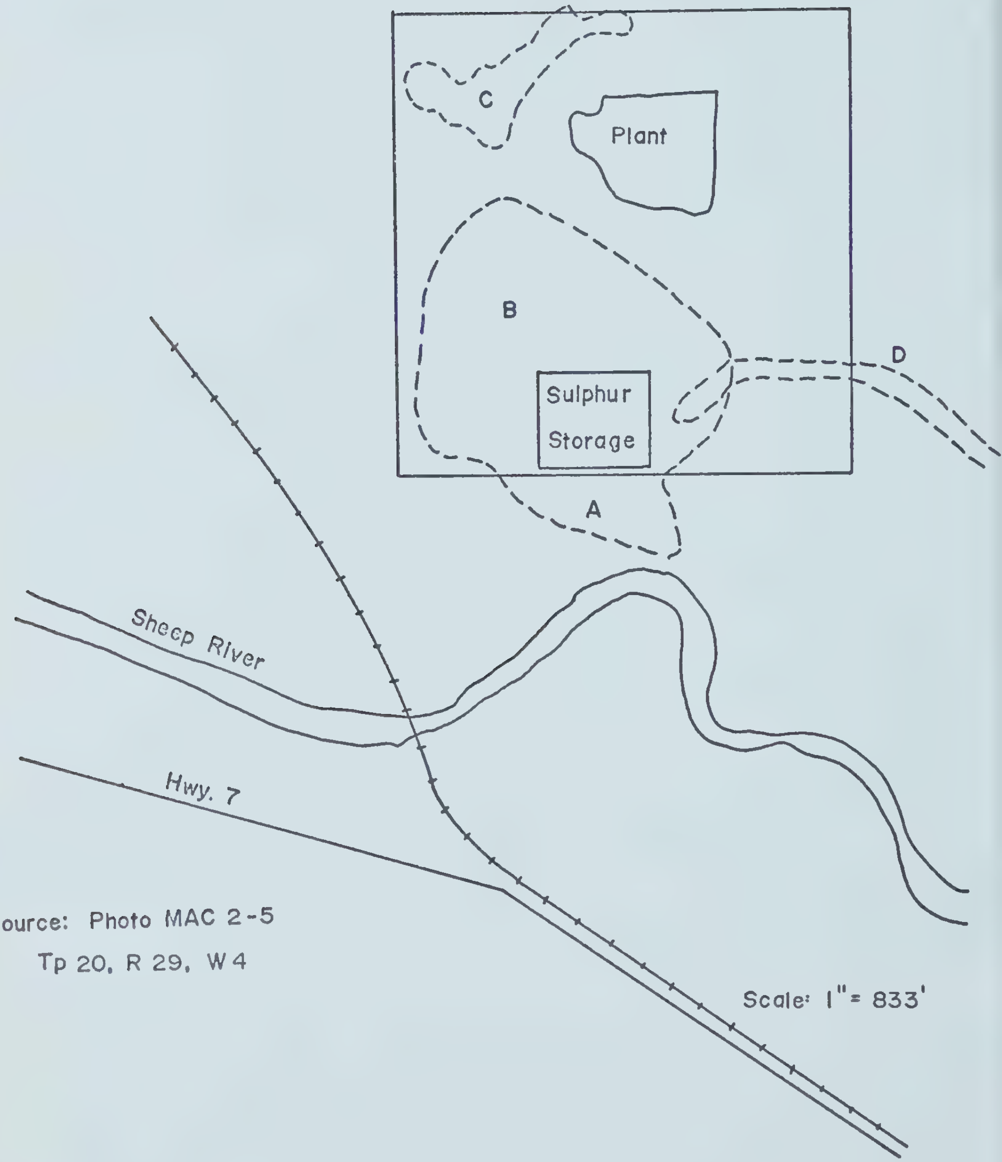
Nearer the processing plant, other vegetation was examined for possible industrial influence. Trees were found that were variously stressed due to nutritional disorders such as in Figure 42 as well as from mild SO_2 doses as in Figure 43. Stress symptoms such as in Figure 43 were not noted in early July, suggesting a late summer exposure possibly related to the August start-up of the gas plant. The symptoms were very local to the gas plant, however, and except as indicated above were not noted at distances over 200 yards.

(c) Remote Sensing of Vegetation Stress:

In order to determine the degree of general vegetation stress in the OKOTOKS area, air photo using FCIR film was obtained during four successive years, starting in 1969. Section II outlines the response characteristics of FCIR film and its use in vegetation stress analysis. The prinicples outlined were followed in making the analysis that follows.

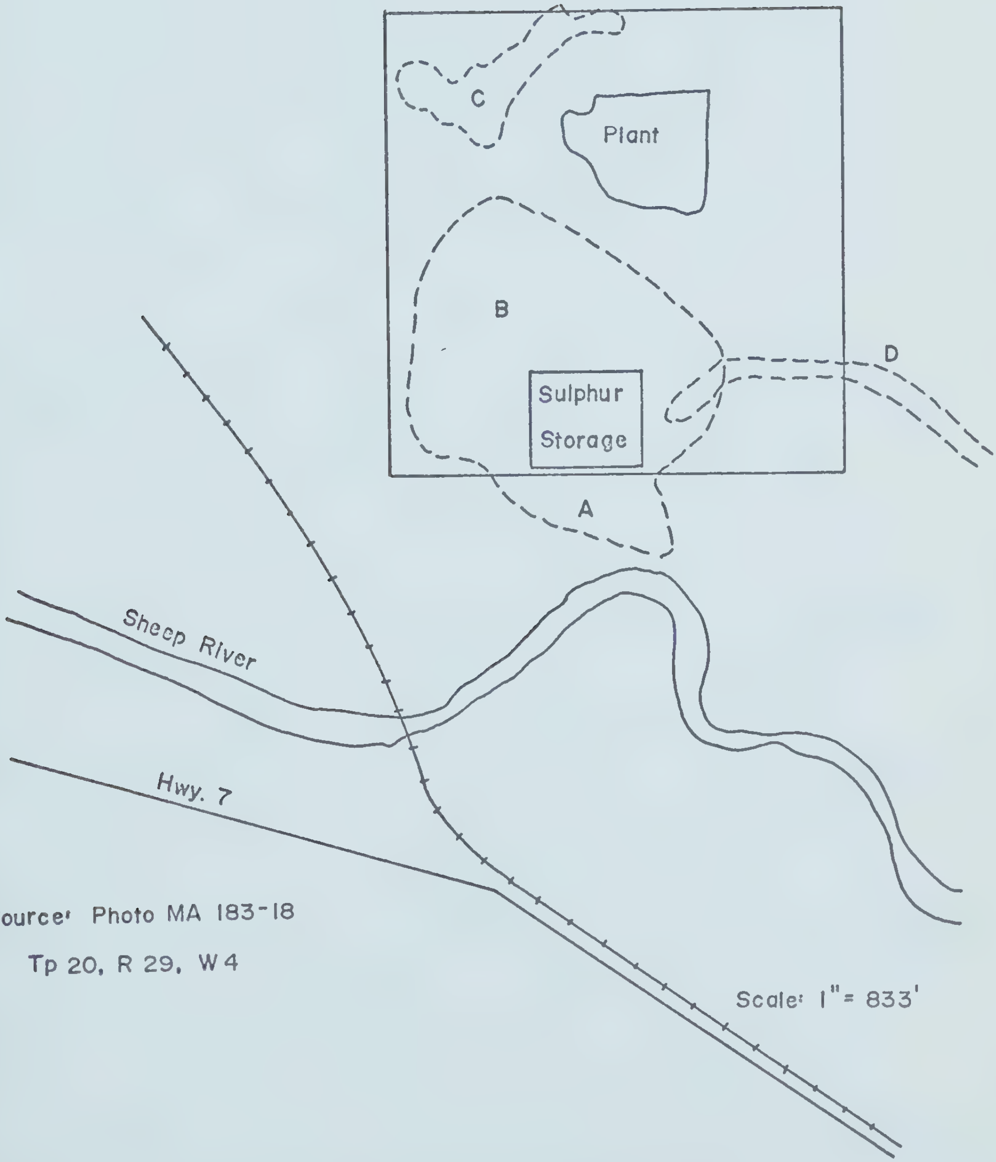
Figure 44 is a view of the OKOTOKS gas plant area with FCIR film, and Figure 45 is the ektachrome equivalent. Overlays on the photographs outline areas of discussion. Area A is in each photo south of the sulphur storage and is that which has been affected by sulphur dusting. The area is very restricted as emphasized by the soil sampling and by the air photo. The absence of the normal tones in area A suggests an effect in the vegetation. There is also a suggestion that this area has increased in size during the interval 1969-1972. However there is nothing on the film to suggest the difference in soil pH which occurred between 1970 and 1972. Other differences as are apparent between the photographs for different years are seasonal variations in the vegetation, and variable film chemistry.

Area B is a "halo" which could be misinterpreted as sulphur storage effect, but is infact normal sparse populations of graminae with the usual seasonal variation. The area to the immediate east of the sulphur storage in area B is the most



Source: Photo MAC 2-5
Tp 20, R 29, W4

FIGURE 44. FCIR. photo of Okotoks plant with discussion areas outlined (1969).



Source: Photo MA 183-18

Tp 20, R 29, W4

FIGURE 45. Ektachrome photo of Okotoks plant with discussion areas outlined (1969).

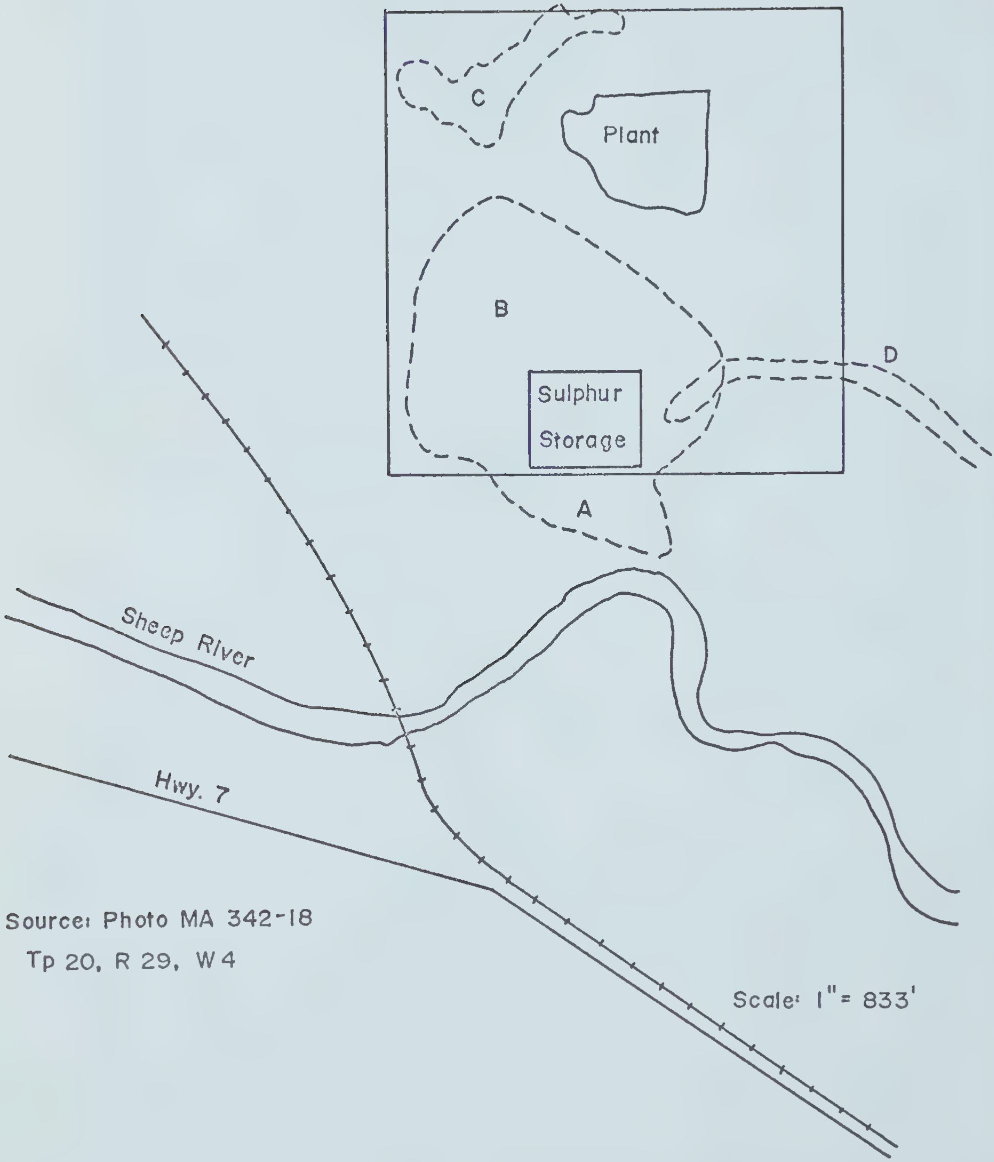
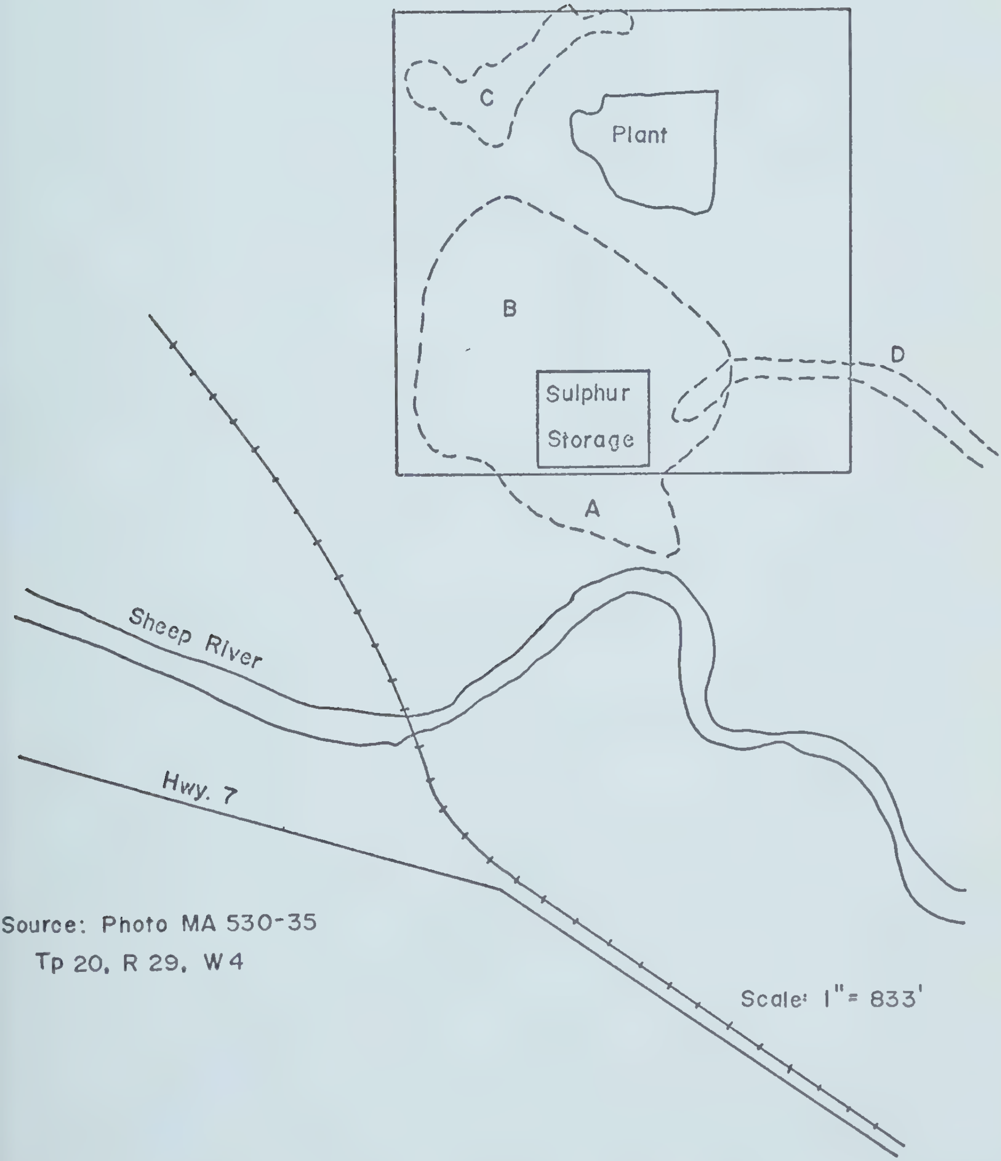
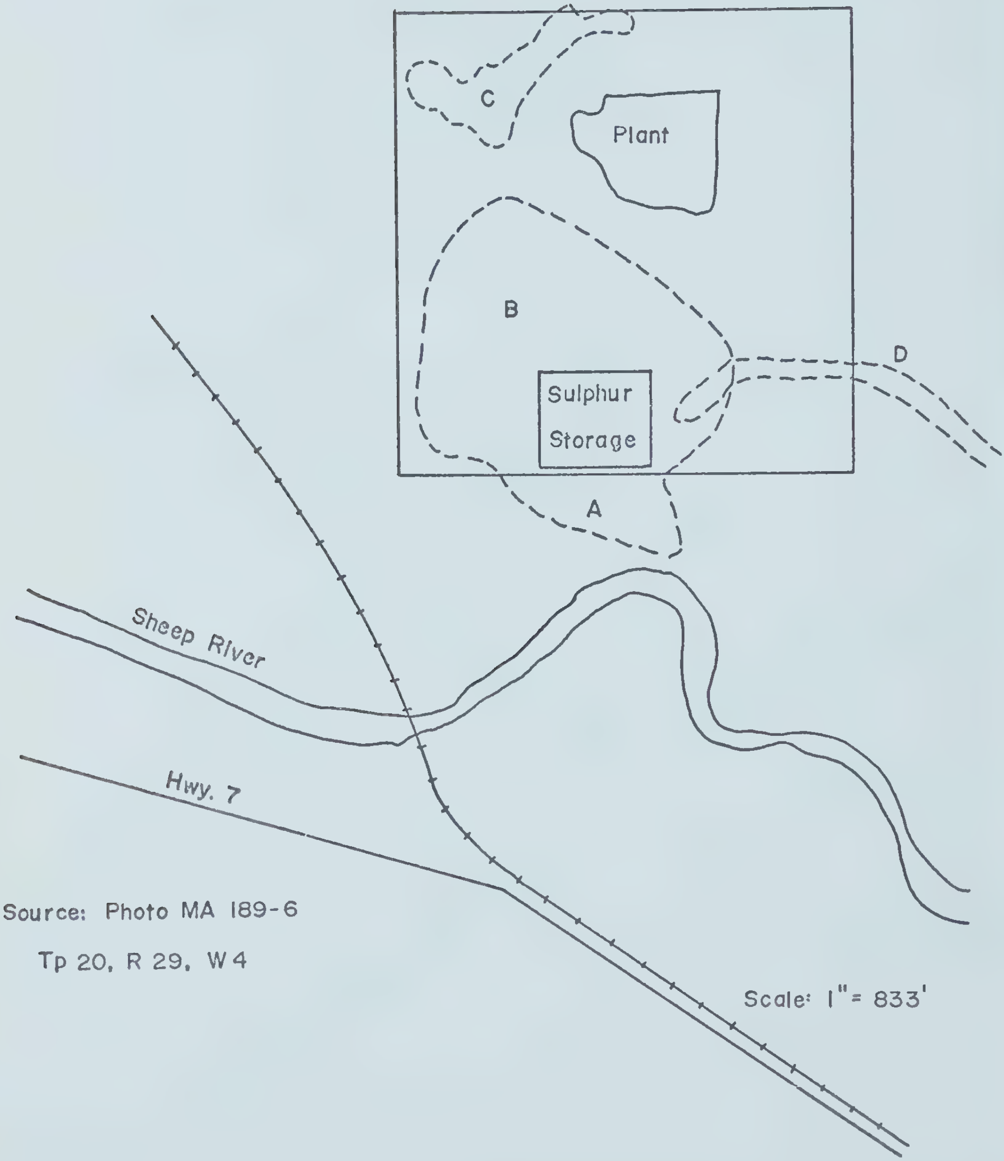


FIGURE 47. FCIR photo of Okotoks plant with discussion areas outlined (1971).



Source: Photo MA 530-35
Tp 20, R 29, W4

FIGURE 48. FCIR photo of Okotoks plant with discussion areas outlined (1972).



Source: Photo MA 189-6

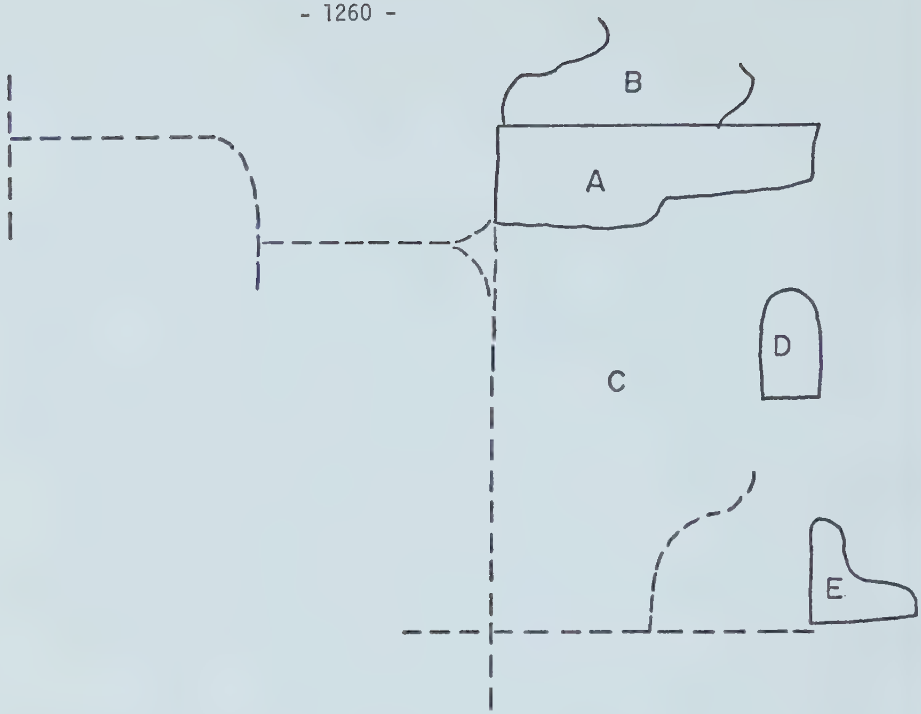
Tp 20, R 29, W4

FIGURE 46. FCIR photo of Okotoks plant with discussion areas outlined (1970).

affected.

Area D is a small stream which passes to the north and north-east of the sulphur vats. The effect of vat effluents is indicated in the stream (see Figure 36) but the water course is quickly restored. Figure 37 corresponds to the point of intersection of the stream and the road that passes on the south of the sulphur storage. Complete recovery is noticeable at this point in the FCIR aerial photographs, as well. Additional features of areas A and B during each year are those associated with the grazing patterns of animals to the east of the sulphur vats.

Area C is a small vegetated ravine to the north-west of the gas plant and was the only area near the plant that contained SO_2 stressed vegetation. Figures 42 and 43 are of plants in this area. The FCIR film suggests plants under stress but does not provide information about the cause of the stress, except through association. Those trees and brush associated with a south facing slope are stressed by normal environmental factors viz: over-heating. Mild SO_2 symptoms were scattered through the trees on the south edge of the ravine, but are not visible in these photos. Seasonal variations were also apparent, but groups of trees that show seasonal stress show it consistently from one year to the next. Figure 49 is a view of the north hill and south-facing slope. Areas A and B is where the photographs in Figures 38 and 39 were taken, and where somewhat higher sulphation levels were noted, with



Source: Photo MA 530-19
Tp 21, R 29, W 4

Scale: 1" = 833'

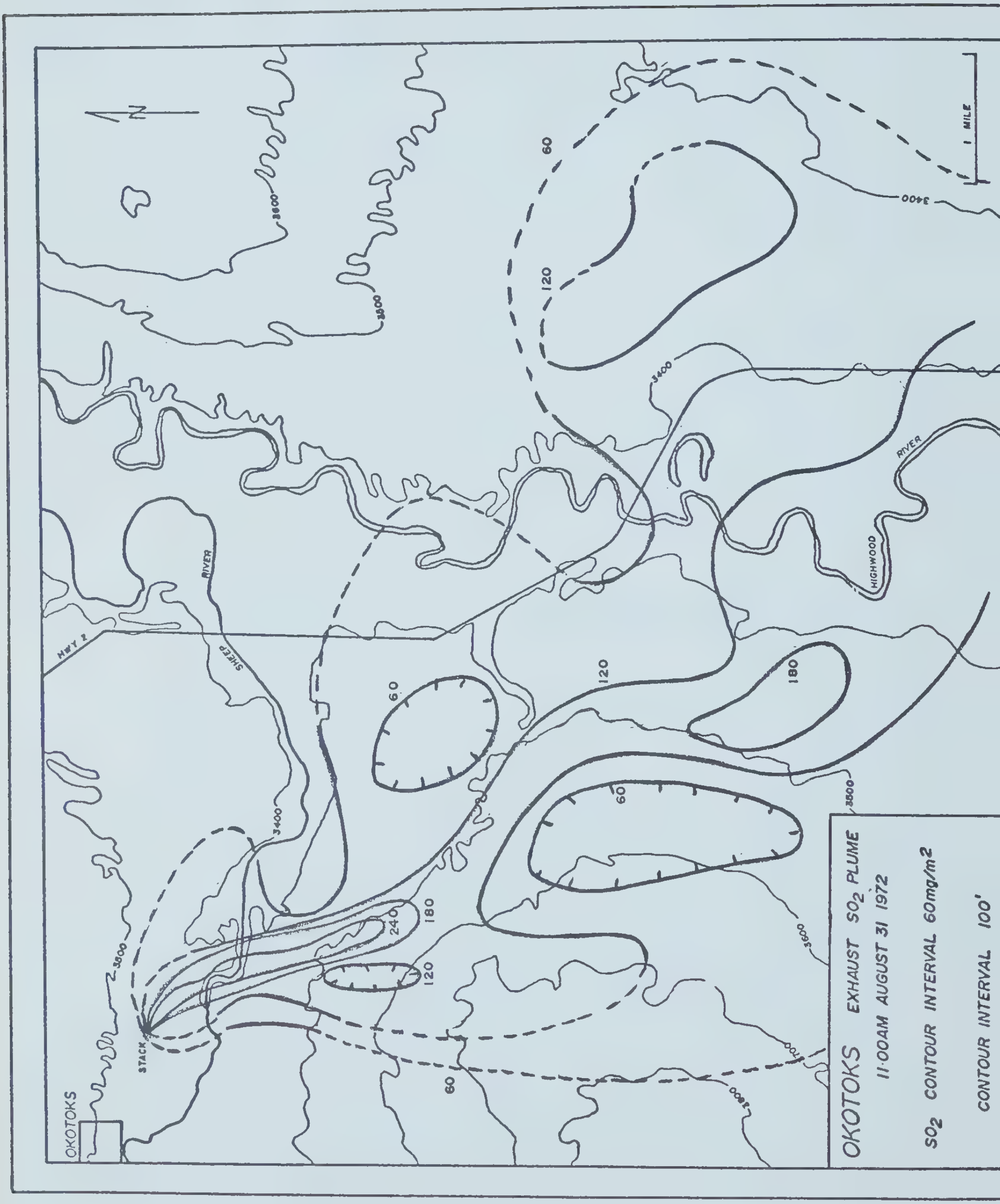
FIGURE 49. FCIR photo of north hill crest and slope near Okotoks plant w discussion areas outlined (1972).

a suggestion of a lowered pH, as well. The vegetation in areas A and B was normal for the time of year and geographical position. Area C was seriously over-grazed and no other stresses could be seen. D is a farm woodlot showing the normal tones of vigorous deciduous growth. Area E is Populus and Salix in their usual association and vigor.

A large number of FCIR and color air photos were examined to attempt to relate stress as is shown in the films to any consistent position pattern in relation to the gas plant, and none was found. Normal environmental patterns in the vegetation were consistent with the over-all ecosystem.

(d) Remote Sensing of SO_2 Plume Position and Concentration:

In order to determine the degree of conformity of an SO_2 plume from OKOTOKS gas plant to a gaussian pattern, remotely sensed SO_2 data were obtained on August 31st at 1100 hours, with an airborne correlation spectrometer as outlined in section II. Total SO_2 burden was measured and plotted in Figure 50. Meteorological conditions were moderate gusty winds out of the NW at 20 to 25 mph, with scattered high cloud. Diffusion was ample with a super adiabatic temperature lapse rate under a high inversion layer. The plume was found to be highly structured but maintained its integrity for in excess of 12 miles downwind. The plume was singularly non-gaussian due to the effects of wind sheer, and undulating topography. Due to the well developed wind field


OKOTOKS EXHAUST SO2 PLUME
11:00AM AUGUST 31 1972
SO2 CONTOUR INTERVAL 60mg/m2
CONTOUR INTERVAL 100'
N
1 MILE
OKOTOKS
STACK
HWY 2
SHEEP RIVER
HIGHWOOD RIVER
60
120
180
240
3400
3500
3600
3700
3800

at this time of day, no conformity to topography was noted. Further discussion of these points is in the following section.

IV. SUMMARY:

(a) Environmental Sensing:

The technological thrust provided by the space age has produced a large number of sensing techniques that are extremely useful in environmental research and monitoring. New methods are continually being developed and are highly experimental but some are operational and available. Such new sensing techniques when used with established, so called "classical" methods provide an unparalleled opportunity to obtain urgently needed data that will permit an unparalleled and complete understanding of the environment. Some of these new methods were used to obtain the data reported in this document.

(b) OKOTOKS Gas Plant Environment:

Environmental sensing techniques used permitted a detailed picture of the OKOTOKS gas plant area environment. Soil and water sampling at OKOTOKS shows that very local effects are present. Soil pH has been reduced within 200 yards of the sulphur storage area to the point where only low pH tolerant grasses and annual weeds can grow. Beyond this distance plant growth and soil characteristics are normal. The streamlet that is influenced near the sulphur storage has virtually completely recovered within 900 yards of the source. SO_2 stress in vegetation is present in mild doses very near the gas plant and at a 5 mile distance on a south hill crest. Symptoms nearest the gas plant can be associated with this source, and appeared in the vegetation only near the last half of the growin season. Affected plants recovered completely each year. SO_2 stress on the south hill cannot be solely associated with the OKOTOKS gas plant since there are other very strong SO_2 emitters upwind. No stress was noted in vegetation that would be affected by winds from the south and south east where the OKOTOKS plant would be the only emitter. The nature and position of the OKOTOKS SO_2 plume on the day of observation was highly structured and flowed over undulating, heterogeneous terrain to produce SO_2 concentrations that were less than would be predicted by statistical plume models.

(c) General:

There is no doubt that an industrial operation like a sulphur extraction gas plant will have some influence on the surrounding environment. This report details some of these influences near such a plant and points out that they are mainly very local to the source. They are in fact far less severe and more difficult to detect than the very abundant natural stresses that occur daily and seasonally. Notice Figure 51 which shows the normal environmental response of Salix gauca. A large portion of the community is showing the normal growth response of this plant.

(Refer to previous discussion RE: Figure 39). To the eye, this plant is singularly unbeautiful but it occupies an enormous acreage in the Alberta foothills. This is normal environmental response and is accepted. Figure 52 shows animal damage to a grove of Poplar trees. The grove was virtually destroyed by this action which is also accepted as normal. In Figure 53 is shown a stand of Populus tremuloides almost completely defoliated by insect attack (shown at closer range in Figure 54). If such an attack lasts for more than two seasons, the trees cannot be expected to recover. Yet, this stress which is widespread in nature is accepted as normal. However, the type of SO_2 stress in the trees shown in Figure 40, which is virtually invisible to the eye (except at close range) and from which the trees can recover annually, may not be acceptable. This seems to us to be very inconsistent, especially in view of the necessity for natural gas in our society.,

However, such industrial encroachment as occurs must be monitored as part of an ongoing program to make certain that the environmental stress is kept in control and within reasonable limits, but must be assessed in a frame of reference that involves the total ecology, not just a single small community of trees or a streamlet.

This report also proposes that process controls and guidelines must include the environment as a substantial input into future rulings as might occur. Surely we have passed the point where 'emissions' are not the only concern in controlling industrial impact on the environment.

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R.M. Holmes, B.Sc., M.Sc., Ph.D., M.Sc., F.R.M.S., P.Ag.

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B.L. Bullock, B.Sc., M.Sc., P.Eng.

V REFERENCES

The volume of literature concerning air pollution, environmental management, vegetation stress, monitoring methods, etc. is very large and is increasing rapidly. While a large number of references were used in the preparation of this report, they are not referred to directly. The following list are some of those consulted during the writting of the various discussions. It was not our purpose to present an elaborate scientific review but we are attaching this list for the reader, who may upon reading them, be lead to inumerable others in the literature.

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QUESTIONING BY THE AUTHORITY

DR. S.B. SMITH

One question, Dr. Holmes. In the evidence for the drift of SO_2 from Calgary, have you got a specific source?

DR. R. HOLMES

Yes, on the east side. I wouldn't want to get more specific than that. We followed a nitrous oxide plume for about fifty miles one day under an inversion from the east side of Calgary.

DR. S.B. SMITH

Thank you. Mr. Plum, with regard to the operation of the Okotoks plant, I wonder about two things: where you pass the effluent down onto the flat; and with your plans to combine effluents and look after surface run-off, would your preference be, if they could be made innocuous, to pass all effluents to the Sheet River? Would this be more convenient and less costly than re-injecting?

MR. E. PLUM

I'm not quite sure because we'd have to check how much treating we would have to do. When you add these two waters together they may come out just about pH 7, I'm not sure. We haven't tried it yet; if we didn't have to treat it it would cost less to pass into the Sheep River.

DR. S.B. SMITH

I don't think pH would be the critical thing in itself, because I think the Sheep River could accept a relatively small effluent like that without any difficulty, but I was thinking more of the constituents-- if fish could live in it, for instance, which is the common method now of making your decision. It's about the only criterion really for wild or natural waters that the Canada Water Act and the Canada Fisheries Act accept -- whether it's harmful to fish -- and it's about perhaps the best criterion. It would seem a simple matter just to put some fish in a tank between the river and your ponds. But it did occur to me that by combining the two sources of water, if there were any appreciable retention time on that little flat you could then get rid of it. I wondered if your intention was, if that were possible, to simply let it go into the Sheep River, which is short of water at some times of the year, by the way.

MR. E. PLUM

Well, that would be the preferably way for us, but we'll have to check it and see. I know right now the fish will not live in the lagoon water.

DR. S.B. SMITH

They won't?

MR. E. PLUM

No. It's got high salt content from the ziolyte softeners.

MR. W.A. FLOOK

Mr. Plum, you indicate that when the plant was designed the stack was designed for the recovery efficiency of the trains as between 94 and 95 per cent.

MR. E. PLUM

That's right.

MR. W.A. FLOOK

At a certain throughput. Today your're operating at about 80 per cent of that throughput. Is this correct?

MR. E. PLUM

Yes.

MR. W.A. FLOOK

But do you think, even at this reduced rate, you are apprehensive about having to meter recovery of 96.5 per cent?

MR. E. PLUM

We might be able to reach it. Everything would just have to be optimum. To get any particular level, you have to be able to convert more than that average figure to average it out. We'd probably have to go up to 97 in some cases to get this 96.5 on a continuous basis.

MR. W.A. FLOOK

But, possibly with a small further reduction in throughput you might be able to get there. Or is ther, in your mind, no direct relationship between your throughput and your concentration in the stack?

MR. E. PLUM

There's not that much relationship. Catalyst volume is one of the things that helps you recover sulphur in the Claus reaction, and I think we have more then adequate catalyst volume. I don't think that reducing throughput, which would improve the volume relationship, would help us. I think we've gone as high as we can.

MR. W.A. FLOOK

You don't think the dilution factor in the stack alone would reduce your stack concentration sufficiently to allow you to meet it?

MR. E. PLUM

It would reduce it, but it's not the amount of stack dilution that counts, this 96 or 97 per cent recovery. It's between what comes in the plant and what you recover on the outside before it goes to the stack. Reducing the rate of gas-in doesn't improve your efficiency.

MR. W.A. FLOOK

In other words you might be able to meet stack emission concentrations but not recovery efficiencies?

MR. E. PLUM

Yes. We are meeting the present stack emission -- we're better then meeting it. Our maximum rate is 26.2 long tons. We are in around the 20 long ton per day rate, but that still does not get us up to 96.5 per cent recovery.

MR. W.A. FLOOK

No. Of course, the only thing that'll do that is the efficiency of your Claus reaction.

MR. E. PLUM

Right.

MR. W.A. FLOOK

You indicate that you will collect your runoff water in a pond for treatment.

MR. E. PLUM

Yes.

MR. W.A. FLOOK

What type of treatment have you get in mind?

MR. E. PLUM

Whatever's required. If it's acidic, we will lime it to make it neutral.

MR. W.A. FLOOK

You have another lagoon with alkaline water in it that conceivably could be used for that. You say that here.

MR. E. PLUM

Yes.

MR. W.A. FLOOK

So really you could have put that water into the other pond?

MR. E. PLUM

Yes, we're thinking of that.

DR. W.R. TROST

The plant has been operating since 1959, is that right?

MR. E. PLUM

Right.

DR. W.R. TROST

And its rate of production is falling off in this last little while. Is that because of the market, or because of the supply?

MR. E. PLUM

Supply.

DR. W.R. TROST

It's been said many times during the hearings that the life of a plant is limited to perhaps twenty or twenty-five years. Is that the case for this plant as well?

MR. E. PLUM

Yes. The latest figure I have seen is about 1988.

DR. W.R. TROST

And, during the remaining years the feed to the plant will steadily fall off, I understand, as you reach the end of your reserve?

MR. E. PLUM

Yes. In about two years we are anticipating putting ocmpressors to keep the plant feed up at a rate where we can operate the plant.

DR. W.R. TROST

What will happen to the plant when you have used up your feed gas?

MR. E. PLUM

If we don't find any more gas, I guess it shuts down.

DR. W.R. TROST

Is it possible to use that plant by shipping in gas from more distant fields?

MR. E. PLUM

Possibly. But, again, that depends on the economics, who owns the fields, and various things of that sort.

DR. W.R. TROST

So this is perhaps one of the first examples in which a plant is over the hill, as it were, and running towards its fated end. Is that right?

MR. E. PLUM

That's quite possible, yes.

DR. W.R. TROST

Now, Dr. Holmes, we've been very interested in the false color technique that you have been showing us which indicates with certainty the condition of plants, though as we knot it doesn't indicate animal life, corrosion or things of that sort. I was beginning to become interested in the difficulty or the advantage, I'm not sure which it is, that the filmmakers are presenting you with. They're changing their dyes a little bit each year. They're giving you better pictures, but they're raising the dickens with your last year's work, aren't they?

DR. R. HOLMES

One has to understand, I suppose, Kodak's predicament in trying to make a better product. But the trouble doesn't end there; it ends, of course, with the man who exposes the film and the longer the time of exposure the less freedom he has in his aircraft operation to get the picture taken. And that's not all -- we're only two-thirds through. Actually it's half the problem, because fifty percent of it and sometimes more belongs to the man in the darkroom who has to manipulate the chemistry to get a good image back. How he controls that temperature, and the chemistry and pH control in your solutions determines whether it's got a big strong shift to the blue or a brilliant shift toward the red, or whether or not it conforms to Kodak's original specifications. It a black art. But on top of that, it has only been about four years since Kodak really had enough thrust from the scientific fraternity to even get interested in producing very much false color film. It was devised as a military weapon; it's now an environmental tool, and is being used universally, and so they're getting after the problem. During these formative years we must expect this kind of trouble with almost any method of this kind.

DR. W.R. TROST

Is it, do you think now, reaching a kind of a standardized level, or at least the changes have been....

DR. R. HOLMES

Well, I'd sure hate to guess the Kodak's technicians on this regard but the art of interpretation is settling down into something that's just a bit more fundamental than it used to be. It used to be pretty pictures. And it used to be a lot of interesting things, but the tendency is to, when you have something like this come on the scene, it's too easy to assume that this is going to do the job.

DR. W.R. TROST

Is it possible to get the art so developed that you can in fact, through light intensity measurements, make more analytical statements about various rates of or states of growth?

DR. R. HOLMES

Yes. The Canada Centre for Remote Sensing with which I was once associated bought up an enormous batch of false color film from Kodak and is running a standardization curve, color balance curve, on this single batch produced by Kodak, hoping to reduce the variability to make it available to groups like this.

DR. W.R. TROST

Now, you know we've also been very interested in the plumes and what happens to the plumes. Thinking of your colored graph of measurements, two things that were interesting were, first of all, that it did substantially retain its integrity as a plume over a considerable number of miles, didn't it?

DR. R. HOLMES

That's right, it did. Plumes tend to do this unless the wind is very light and variable and also (both conditions must be met) if it passes over widely varying heat fields on the surface; then it tends to break up into little parcelized packages here and there. Otherwise our measurements tend to give the impressions of a very strongly lobed plume when this is not the case. In this particular example the winds are strong enough to maintain the integrity of the plume.

DR. W.R. TROST

Right. Now the picture showed us the plume in a horizontal display, as of course you had to. How high was the plume?

DR. R. HOLMES

About a hundred feet. The inversion layer on a day like that would be about eighteen hundred, two thousand feet above the surface.

DR. W.R. TROST

I suppose when you're doing these things at that height you keep your wheels up, do you? Or do you keep them down?

DR. R. HOLMES

It's not possible to fly the airplane on the ground.

DR. W.R. TROST

But when the high concentration elements reappeared later on, that was because of the contour or some upthrust below; it could have been a warming effect.

DR. R. HOLMES

Yes. That's a very important phenomenon. The second one that contributes to it is if the wind tends to concentrate in a particular direction for a time it may blow a significant part of the plume in a direction, then it will shift ten degrees leaving this package of plume sitting out here by itself, and now blow theplume out here. It tends to give big packages of plume here and there as the wind shifts in speed and direction.

DR. W.R. TROST

When the wind blows in one direction you implied that you get a little bit from Calgary; when the wind blows from the other direction do you get even?

DR. R. HOLMES

No, I don't think so. I think Calgary's got everybody beat.

Brief Presented by: Mayor W.G. Milne
Summer Village of Ghost Lake

I am a practicing architect in Calgary, a member of the Planning Advisory Commission, and as well the Mayor of the Summer Village at Ghost Lake. Thank you very much for the opportunity of letting us speak, because I think this is, to some extent, long overdue and it is really a marvellous opportunity to raise some points that should be raised. My particular presentation is going to be a little different than most you've heard because my concern really is visual pollution. You can get concerned about your lungs and about your animals and that sort of thing, but perhaps in some respects the visual pollution is really equally as important.

The summer village of Ghost Lake is forty miles from here on the 1A Highway. It is saddled between the Jumping Pound field and the Wildcat Hills field. Perhaps I'm not really talking to the point because I'm not so concerned particularly about sulphur extraction plants but really plants in general. I understand the hearing is to be pretty broad and I think this might be the only opportunity that I will have to speak to this point so I'm taking this time.

We have, west of here, in the hilly foothill country, really outstanding physical countryside. I think some of us lose sight of it and it doesn't really get brought to you until people from Eastern Canada or the Prairies visit, and then you start recognizing through somebody else's eyes just what a great piece of land it is west of here. What's been happening I think with the gas plants is that they have been tolerable in the agricultural areas out of the foothills, back in the more flat lands in Alberta, but right now we have had two new plants built west of Calgary and in land that I think has a better and higher use. I think it's unfortunate that the plants are being put where they are because they're really crippling visually a very large area. I am talking about the two sections on each side of the plant which is severely affected by the kind of plant and the size of the plant. Then flowing out of that is the fact that because of the geophysical work, the foothill country that is wooded is being cut up and there are pumping stations, and well drilling sites. The total impact on that environment is really of a large magnitude.

We recognize that we went to our summer village because it is a great place for recreation, and in the short term I think the plant is having a detrimental effect on the recreation. In the long term, because it's in the Bow Corridor and the Elbow Corridor, it is going to have a serious impact as our country residential districts flow out of Calgary. I might say that in terms of the Fina plant at the Wildcat Hills, the residential twenty acre subdivisions now are within something like seven miles, so it's not like it is tomorrow or a long way down the road, it's almost there now. I know there is a tendency to say, well, gosh, you really can't put much of a value on what that plant does to a piece of land. I think if any of us have had an opportunity to see this magnificent view, it isn't where you would want a gas plant of the size that is being built. I think you realize if you have a summer place or if you contemplate one and then see in that magnificent panorama that you get from some of the foothills areas west of here, those plants sitting in commanding positions, and totally dominating the area, you realize then what an effect it has on the environment.

I know sometimes these philosophical arguments about value of visual environment are shomewhat hard to accept, but we can relate it to what really happened with the national parks. We have these magnificent national parks because the first director was able to ge back to Parliament and convince some not on visual grounds but on economic grounds that these parks should be set aside, because of the large flow of capital that would flow into the country from the recreational-tourist point of view. Of course that really has borne out because we have kept our mining, logging and the industries and we won that battle in the parks. It is really reflected in the high place now that the tourist dollar plays in our Canadian economy. I say we have the same situation and we should be able to learn a bit from that history in the parks. We have the same situation, particularly in the Banff Corridor, and in our foothills; country that's close to the major population centres, and on good thoroughfares. The Banff Corridor, west of Cochrane, and for five or ten miles on each side, truly has an incredible potential from a recreation-tourist point of view. I think we're doing the land a disservice. We're allowing gas plants to go in locations that truly dominate large pieces of landscape. I know we have to get the resource out, I'm really not a wild conservationist in this respect, but I think we have to take another look at how we're doing it. Certainly, just because an area is zoned agricultural, I don't think it means that we can plop down buildings, and plants, that are truly industrial in character in the middle of it. I think we really do have to start looking at these particular areas; the ones that are highly used from a recreational point of view, close to Calgary for a day's outing, and that Bow-Elbow Corridor. We have to examine them, we have to zone and to locate these plants as close to a field as we can get, but still try and do it in an area that generally doesn't have the high potential that so much of the land west does have. I think we're going to have to locate them in places, maybe into coolies, so that they don't have an effect over such a great area. The first impact you get after leaving Cochrane, and I'm talking about something like ten miles from the Fina plant at the Wildcat Hills, of course, is this plant. It just grows and grows as you drive along the scenic 1A Highway until it's the major element on the landscape. I think we have to start being conscious of this aspect so that we put the land totally to its highest and best use and not just drop the plant in where, because of engineering approaches, it just happens to be the shortest line, and the flatest land, and disregard altogether this other aspect. We have to zone and consider plant locations in the foothills country west of Calgary, and I expect the same thing will apply west of other high population areas like Red Deer, Lethbride and Edmonton. We are not being fair to the land in the way we are handling that. Our summer village accommodates about a hundred families and the impact on them is obvious because anytime you want to take a panoramic view or just stand on a hill and look around, again the first thing that hits you on the landscape is this particular plant. The one north of Cochrane may have been accidently handled in a somewhat better manner as it is in a ravine and is somewhat screened. As I say it may have been accidental, but it actually seems to be a much better planned location. As a result it doesn't have the great range of impact on the community.

I talked about how in fact the national parks had been set aside more on economic grounds than any other grounds. What I did want to say also is that the nine sections that surround, for instance, the Fina plant at the Wildcat Hills, has a potential in terms of twenty acre subdivision developments generating something in the order of $32,000 a section or about $300,000 in taxes a year. That is just the immediate land. I think you might say, well, maybe the development will go ahead anyway. It doesn't really follow because land is turning over in that area, very, very quickly, for country residential but there is a section across the road allowance from the Fina plant and although it's priced considerably less than anything else in the area, it hasn't sold in three years. Whereas, a section ten miles from the plant or five miles from the plant, if it is put on the market, it will be bought up within a period of a few months. I don't think there's any question that the plant has a real influence on the land values around the plant and the subsequent use that it can be put to. I think that it really is significant in the near future that land have the capacity to generate something in the order of $300,000 in taxes. The beauty of that is it is usually taxes for services that really aren't needed there, because, as you probably know, in the twenty acre subdivisions, the people put in their own well, septic fields and they do their own internal roads. The burden on the community is fairly light. The major road allowances are usually there anyway because of the agricultural purposes and so it has the potential of generating considerable funds in the community in terms of schooling and community facilities.

I think perhaps a person could talk to some length this particular point, but just to recap, I think the land, or the areas should be, zoned considerably better than they are now; that we should be locating plants not just on engineering principles, but on good physical planning principles. I think we should examine the overall picture of the potential of the income from the plant, but I think we should also give consideration to the income from the land itself.

QUESTIONING BY THE AUTHORITY

DR. W. R. TROST

Thanks very much, Mayor Milne. We're pleased to have this submission to these hearings, but you'll be interested to know that, at the request of the government of the province, we are conducting comprehensive inquiry through public hearings into land use and resource development in the whole of the eastern slopes in the province, which is the mountain and foothill country. We will do it on each sector, on a watershed basin, going into each of the major cities and the population, and the water basins behind them: Lethbridge, Calgary, Red Deer, Edmonton, Grande Prairie, following out the kind of thought that was implicit in what you were saying. We'll be doing that next spring, so I fully expect to see you again next spring.

DR. S.B. SMITH

In regard to the economic potential you spoke about in terms of the restrictive practices in the national parks, comparing our annual revenue from the national parks with what it might have been had we used them industrially, I think is a valid comparison. I wonder if you'd care to comment on the relative potential of the area west of here -- which is very beautiful indeed on both sides of the river, but particularly the north side of the river -- in terms of buying it up for public land rather than subdividing it into country estates. I think they're two quite different things. The revenue in the second alternative, country estates, is obviously to the advantage of the municipal districts in terms of taxation. Would it generate the same kind of tourist potential revenue if it were subdivided into estates? Would you care to comment on that?

MAYOR W.G. MILNE

I think you have put your finger on a rather sensitive spot, because it is distressing to most of us to see the subdivisions just run wild right out to the park boundary; that's really what's happening, and it's getting away from us. A number of us, including osme of us of the summer village, have been concerned about this sort of thing because we recognize the value tourist-wise or even local residents-wise. I think you might be interested; a group of us were instrumental in approaching the government and having a fairly large section of the land that became available purchased for those purposes. It seems to me that we should be doing this in large blocks through this foothill country, because certainly in the long term the potential income abilities of that land must be equal to what is in the national park itself. We have, west of here a very short distance, areas of equally outstanding qualities that are in the national parks themselves, and we're just gradually chipping them away with the subdivisions and with the industrial uses that are going in, and it's distressing. I really would say that we do have in our hands, if we approach it sensibly now, the ability to make the best and highest use of this land.

DR. S.B. SMITH

Now that the Chairman has informed you of the hearings next year, it would seem to me that you are in a unique position to bring this point through in perhaps a more analyzed in more detail and with real data, sometime in the future when we hold our land use hearings.

MAYOR W.G. MILNE

I'd like very much to do that; unfortunately the little summer village of Ghost Lake and myself, personally, don't have the resources of some of the people that have made presentations here today, but we would like to try and develop a comprehensive brief for you for these next hearings. I'd like to apologize because it really caught us short. We were aware that the hearings were coming along and then all of a sudden they were here. We're here on quite short notice, and so it isn't what you'd call a very professional brief, and I apologize for it.

MR. W.A. FLOOK

Mr. Milne, although I happen to be one of those who feels that a plant has a certain beauty and magnificence of its own, I agree with you that its presence in a beautiful landscape like the foothills is somewhat anomalous. Since a certain number of them are, indeed there already, is there anything you can suggest that might be done to minimize the incongruity of a plant in that landscape -- something like the growth of trees around it, or some form of landscaping? Would this tend to minimize that awful impact that annoys you so much?

MAYOR W.G. MILNE

Yes, I think there are a number of things. First, I think a minimum amount of berming should be a requirement of a plant in a flat area. I'm talking about a berm that would mean that you might visually block the plant from being seen from an automobile, not maybe from up on an adjacent hill. A nominal amount of tree planting would make a great deal of sense. I would expect the plant operators might be a little distressed there because I think generally they like to keep the plant area clean, for security and fire protection. Another thing: it's always an engineering solution to paint everything aluminum, but it seems to me that just a very simple natural color -- now it might conflict with all sorts of things in terms of heat gain and that sort of thing -- but it would soften the impact of the plant in terms of a warmer color. The brown or tan or buff colors would make a world of difference to the plant. Your eye wouldn't suddenly just zero right in on the plant. It would integrate it much better with the general area. There's always a tendency to get engineering solutions around plants, and they become industrial solutions. Actually the way plants are handled, we truly wouldn't allow that to be in some of our second-rate industrial areas in the city of Calgary. For the immediate environment around a plant we would expect landscaping, we would expect berming, we would expect some color coordination with the industrial area that was going in. And it does seem inconsistent in the recreation-tourist oriented area into which the plants are now moving. It does seem curious that we haven't at least established a minimum kind of architectural control on the plant. I'm not talking about anything serious. I mean just very simple color control, landscaping, and berming.

Submission to the Environment Conservation Authority

East Crossfield D-1 Plant

October 16, 1972

Southern Alberta Jubilee Auditorium

Calgary, Alberta

Presented by: A. Neidermayer

AMOCO

Amoco Canada
Petroleum Company Ltd.

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A. Recommendations

It is recommended that the present regulations governing the ground level concentrations of SO_2 and the levels of sulphur recovery not be changed for East Crossfield since there has been no apparent evidence of adverse effects on the environment.

B. Purpose

The purpose of this brief is to review the operations of the East Crossfield D-1 Plant, showing the improvements which have been achieved by the operator in reducing contaminant emissions and the results of our environmental monitoring programs. Finally, it is the purpose of the submission to make recommendation such that the Environment Conservation Authority may suitably advise the Department of the Environment regarding operations of this plant.

C. Summary

The East Crossfield D-1 Plant has been in operation for about five years. During the initial operation of the plant, operating problems were experienced such that the sulphur recovery levels were below design. Plant modifications were made and the sulphur recovery levels were increased to above approved levels. Several improvements were also made in the plant and in the field to reduce contaminant emissions and to improve air quality.

Environmental monitoring programs have been conducted which establish that no evidence of environmental problems due to SO_2 emission exist. In the immediate area of the sulphur block, we feel that the installation of the sulphur slating facilities has eliminated a localized sulphur dusting problem. No other environmental damage has been detected. We have conducted a comprehensive pollution monitoring program and we propose to continue our efforts in this regard.

This report also concludes that with the present state of the art of tail gas cleanup, the increase of sulphur recovery cannot be considered conservation of a natural resource. The use of a more valuable natural resource to recover a less valuable resource is not in keeping with a philosophy of total resource management.

D. History

The East Crossfield D-1 field, located approximately 30 miles north of the city of Calgary, was discovered in 1960 with the drilling of Pan Am Fargo G-1 Cross Lsd. 16-14-28-1-W5M. Development drilling took place during 1967 and 1968. The D-1 plant started up in February 1968. Current production rates are 55 million cubic feet per day of sales gas, 1600 long tons per day of sulphur and 500 barrels per day of condensate.

A total investment of $36,000,000 has been made in the D-1 project. Thirty-six wells in the unit cost $8,500,000, gas gathering system cost $5,100,000 and the plant cost $22,300,000. Land acquisition and dry hole costs have not been included.

The average operating cost of the complex has been approximately $2,300,000 per year. This is made up of $800,000 per year to operate the wells, $300,000 per year to operate the gas gathering system and $1,221,000 per year to operate the plant. The Crossfield Plant ships about 500,000 long tons per year of sulphur by rail. The rail charge is about $5.50 per long ton. This $2,750,000 per year of rail charges and other indirect expenses are not included in the above operating costs. Presently, there are about 50 people employed by Amoco Canada who are directly responsible for the D-1 operation. Our payroll is about $400,000 per year to these people. Cumulatively, the operation has contributed $1,451,000 in royalty payments to the people of Alberta. In addition, $740,000 have been paid in the form of municipal and local taxes.

E. Future Plans

In order to continue operations, our plans are to drill an additional 21 wells. This will cost about $6,300,000. The gathering system and the plant will require expansion and this will cost $5,000,000 and $4,500,000 respectively. The total future investment might be $15,800,000. This expansion for continued operation may not be justified if further burdens such as increased royalty payments, higher sulphur recovery levels and stringent air pollution requirements are imposed. The matters now before this Board and others may seriously jeopardize the viability of this resource development project.

F. A Brief Description of the Operation

Natural gas, condensate, sulphur and water are produced from wells and brought into the plant through a pipeline network. Attachment No. 1 is a map showing the unit boundary, wells, gas gathering system and the D-1 Plant.

Attachment No. 2 is a simplified block diagram of the plant operation. The gas and liquids are separated in the inlet separator. Acid Gas (H_2S and CO_2), water and hydrocarbon liquids are removed from the gas stream to make sales gas specification product. The acid gas recovered in the gas sweetening operation is piped to the sulphur plant for elemental sulphur recovery. The hydrocarbon liquids are collected and stored in storage tanks for ultimate sales. Attachment No. 3 is a photograph of the plant complex.

G. Principal Pollution Regulations

The construction and operation of the plant is governed by several governmental departments. These include the Departments of Mines and Minerals, Environment, Labour, Lands and Forests, Wildlife, Commerce, and Agriculture. While several governmental agencies enforce the regulations set up by the government, the principal agency is the Energy Resources Conservation Board.

The principal emission at the East Crossfield D-1 Plant is in the form of SO_2 from the 300 foot sulphur incinerator stack. At the present time, the maximum permitted emission from the stack is 196 long tons per day of SO_2, when the stack top temperature is 1200°F. Our approval also requires the recovery of 95% of all the sulphur entering the plant. The incinerator stack was designed to meet the 0.2 ppm calculated ground level SO_2 concentration.

The plant is operated so that a minimum of gas is flared. In no event are flared gaseous hydrocarbons in any year allowed to exceed one-half of one percent of the total volume delivered to the plant. Moreover, ERCB approval is obtained before any gas is flared in the field. Waste water is disposed of by injecting it into an underground formation -- the Viking -- approximately 6800 feet deep.

H. Problems Encountered

Two major operating problems were encountered and resolved since plant startup.

1. Sulphur Recovery Levels

Immediately upon plant startup, design sulphur recovery levels could not be attained. Attachment No. 4 is the history of the sulphur recovery efficiencies. It was discovered that the hydrocarbon liquid production from the field was considerably higher than anticipated. As a result, more hydrocarbons were coming in contact with the gas sweetening agent (sulfinol). Hydrocarbons have the property of accelerating the degradation of the sweetening agent. The degradation product tends to cause hydrocarbons to be carried into the sulphur plant with the acid gas stream. With the hydrocarbons in the sulphur plant, the capacity of the sulphur plant to recover elemental sulphur is reduced and the hydrocarbons cause permanent damage to the converter beds.

Approximately $1,000,000 was spent to revamp the inlet separation facilities to remove the hydrocarbon liquids and to install a reclaimer in the gas sweetening facilities to remove the degradation products from the gas sweetening agent.

In the meantime, our Research Department conducted tests to determine the optimum converter bed catalyst for use in the D-1 sulphur plant. Their $50,000 study indicated a

4-8 mesh bauxite would be the best suited for this application. The first sulphur train catalyst was changed out in May 1969 and the second sulphur train was changed out in August 1969. The cost of the catalyst changeout was about $150,000. Following the catalyst change, the design sulphur recovery levels were attained.

In early 1970, the sulphur recovery levels dipped below design due to plant metering errors. The errors were not discovered until June 1970. Stack surveys conducted in June indicated the plant was operating above approved levels. The metering errors were corrected following the survey.

2. Sulphur Dusting

During the first three years of plant operation, sulphur in the storage block was crushed and loaded into railway cars. During this operation, sulphur dusting posed a problem immediately around the sulphur block area.

In late 1970, sulphur slating facilities were installed to eliminate the crushing operation and the sulphur dusting problem. The facilities were designed to slate 1400 long tons per day of sulphur and have storage capacity for 30,000 long tons. Loading rate from storage into railway cars was designed for 2500 long tons per hour. The slating facilities started up in April 1971 and the problem of sulphur dusting was resolved.

However, during the initial three years of crushing and loading of sulphur, sulphur dust particles have affected approximately 40 acres in the immediate area of the block. Tests are currently being made to determine if the crop yield has been effected.

> A course of action satisfactory to the farmer has been developed and it should be recognized that the increase in soil acidity is not permanent. The acidity can be neutralized either chemically or naturally by cultivation and planting. Soil sampling surveys and infrared aerial photograph surveys indicate that the migration of the soil acidity has been arrested.

I. Improvements

Numerous modifications have been made in the plant and in the field to increase the recovery of gas, hydrocarbon liquids and sulphur since plant startup and to promote operational safeguards.

1. Safety Valves

All wellheads have been equipped with surface safety valves to prevent a possible uncontrolled emission from a well. In addition, a pressure safety relief valve was installed on each wellhead heater to prevent overpressuring of the wellhead and the gas gathering system. Since 1970 approximately $300,000 has been spent to install subsurface safety valves to also prevent possible uncontrolled well emissions.

2. Corrosion Control

The gas gathering system is designed to mitigate the effect of corrosion. The pipe is externally yellow jacketed and cathodically protected to prevent pipeline external corrosion. A comprehensive monitoring and inhibition program are in effect to prevent pipeline failures. The corrosion inhibition program is monitored with coupons, [illegible] hydrogen probes, X-rays and ultrasonic tests. We estimate the monitoring program costs about $2,000 per year. The inhibition program consists of squeezing chemicals into the wellbore and injecting chemicals in the pipeline at a total cost of $106,000 per year. In addition an initial $7,000 investment was required to install the necessary chemical injection facilities.

Our latest monitoring data obtained in mid-August 1972 indicated an average corrosion rate of 0.389 mils per year in the gas gathering system. Ultrasonic and radiographic (X-rays) inspections showed nil corrosion. In mid-July 1972 corrosion coupons pulled from seven wells indicated corrosion rates between 0.11 to 0.8 mils per year. These rates indicate that the life of the gas gathering system should exceed the D-1 project life.

3. Field Flaring

During the initial installation of the wellsite facilities, 20 foot flare stacks were installed at 35 locations. Beginning in July 1969, the old flare stacks were changed out to 75 foot stacks for two reasons: first, an ERCB directive requiring a stack of at least 40 foot at all sour gas wells, and second, gas well testing operations necessitating the rental, erection and removal of a 75 foot flare stack for each test.

Two operating problems were experienced in connection with the flare stacks, keeping pilots lighted, and the unreliability of devices (flame ladders) for lighting the pilots. Initially, about 35% of the pilots were found extinguished each day. This permitted, in some cases, raw gas to be emitted to the atmosphere. Modified burner tips and the flame ladders designed by Amoco Canada engineers were installed on all stacks. The total cost of the flare stack changeouts and modifications was $360,000. The modified burner windshield design has been patented and is used by others in industry. The Department of the Environment (then the Department of Health) had indicated a necessity for installing an automatic pilot ignitor on each stack. However after witnessing the ease and reliability of the modified pilot ignition, our pilot assembly was approved for use.

4. Water Disposal

In late 1970, a waste water disposal facility was installed to eliminate the use of a surface pit. The facilities include the installation of a separator to collect all plant liquid waste products, a storage tank to hold the liquid waste and injection facilities to inject the waste into an underground formation (Viking formation, approximately 6800 feet deep). In 1971 additional piping was installed such that the gas off the waste storage tank (predominantly H_2S) would not be emitted directly to the atmosphere.

5. Well Cleanup

Formerly, during a cleanup operation of a well, after acidization or condensate soaking to increase the well productivity, the gas and entrained liquids were flared. The entrained liquids caused heavy black smoke. This has now been eliminated by the use of a (Portatest) separator downstream of a conventional separator to remove the entrained liquids. Cost of the smoke elimination is estimated to be about $5,000 per job.

6. Compression Vent Gas Emission

Originally, when seal leaks on the flash gas compressor were experienced, the H_2S gas was vented directly to the atmosphere. In 1971, a vacuum pump was installed to collect the vented gas for disposal into the incinerator.

7. Storage Tank Emission

The H_2S is not completely stripped from the condensate by the flash vessels before the condensate is stored in the plant storage tanks. As a result, H_2S breaks out of the liquid phase and created an unpleasant odor in the plant. A gas blanket previously used on the tanks was found insufficient to retain the vapors. As a result, a stock tank vapor recovery facility has been installed. Since the startup in March 1972, the odor problem around the plant has been considerably reduced.

8. Tail Gas Monitoring

The ratio of H_2S and SO_2 in the sulphur plant is extremely critical to obtaining high levels of sulphur recovery. The East Crossfield D-1 Plant was equipped with tail gas chromatographs to enable the Plant operator to immediately determine the $H_2S:SO_2$ ratios. The chromatographs also enable Plant personnel to determine the volume of SO_2 emitted to the atmosphere.

In April 1971, continuous stack gas SO_2 monitoring equipment was installed to satisfy a Board requirement. The purpose of the instrument is to also monitor the volume of SO_2 emitted to the atmosphere through the incinerator stack. The cost of leasing the continuous stack emission monitor is approximately $1,600 per month and the cost of installing the equipment was about $2,000. Considerable operating problems were encountered such as sample ling plugging, obtaining and maintaining calibrations. During the first ten months of the instrument operation, the average on-line time was only 71%. To date, not all of the operating problems associated with the continuous monitoring equipment have been resolved.

9. Company Research on Sulphur Recovery

The majority of the sulphur plants in Alberta were designed under Amoco patent. Our Research Department developed the design which is licensed to several contractors. The full potential of sulphur recovery from the Modified Claus sulphur plant is not known. Currently, we are conducting a pilot study at the East Crossfield Plant to determine the sulphur recovery efficiency with a third converter installation. Technical information could result in further improving sulphur recovery efficiencies of existing sulphur plants in Alberta.

Only the major improvements have been presented above. There are numerous minor modifications which have improved the ambient air quality around the East Crossfield area. We hope to continue these efforts.

J. Safety

The danger of H_2S is stressed to all employees. H_2S is highly toxic, colorless, heavier than air, and odorless in high concentrations. The residents in the plant area and in the field are aware of the toxic nature of this gas. It is our practice to visit all residents on a yearly basis to outline safety procedures should any unforeseen emergency occur. We discuss mutual problems and answer questions they might have. In addition, a brightly colored notification card (Attachment No. 5) has been distributed to provide ready information in the case of an emergency. The use of this card has not been required to date.

The last visit was conducted in February 1972. One hundred and seventy-nine residents were visited and five complaints were recorded. Three concerned seismic operations in the area, one had a cattle guard which required repairs due to our operations and one resident noted some corrosion and paint peeling off a propane storage tank. Appropriate action was taken on the seismic operation and on the repair of the cattle guard. No action was taken regarding the propane storage tank since the paint peeling had occurred before the D-1 Plant went into operation.

In 1969, a report entitled "Safety Procedures D-1 Gas Gathering System" was prepared. This report outlined the safety procedures for company personnel and other persons in the vicinity. The report also contained locations of emergency facilities (hospitals, police, fire departments, etc.) names and telephone numbers of key personnel (plant foreman, mayor, fire chief, etc.) and names and addresses and locations of all people living in the area. The original report was prepared before it became a mandatory requirement by the ERCB. The report is updated periodically.

K. Pollution Monitoring

1. Exposure Cylinders

Monitoring of the environment was implemented about six months before the D-1 Plant was constructed. Initially, six atmosphere exposure cylinders were installed around the proposed plant site. Today there are 28 atmosphere exposure cylinders located strategically in the field, (see Attachment No. 6). Each station contains two cylinders, one detects the H_2S concentration and the other detects the total sulphur compounds. All cylinders are replaced and analyzed once per month. Amoco Canada maintains 20 stations and the Department of Environment maintains eight stations. Attachments No. 7 and 8 are Amoco's and the Department of Environment's exposure cylinder monitoring results, respectively.

From Attachments 7 and 8, a decreasing trend of the total sulphur concentrations can be seen. As explained earlier in the "Problems Encountered" section, the plant experienced a problem with sulphur recovery efficiencies during initial operations. With the improved sulphur recovery efficiency, as exhibited in Attachment No. 4, a decrease in total sulfation is evident. The peaks are attributed to the atmospheric temperature inversions during the cold winter months. From Attachment No. 8, the exposure cylinder results from stations 2, 3, 4, 5 and 6 indicate that the contaminant concentrations at present (1971 and 1972) are about the same as it was before the D-1 Plant was constructed.

A similar downward trend in the H_2S concentration can be seen, however, not as pronounced as the total sulfation data. The downward trend is attributed to the improved plant and field operating practices. The peaks are again attributed to operations during cold winter months when dispersion is more difficult.

2. Continuous Monitoring

A pollution monitoring trailer is located in Lsd. 7-3-28-29-W4M, about 2-1/2 miles southeast of the plant site. Pollution monitoring instruments are contained in this trailer which include a Davis SO_2 monitor, an AISI H_2S Spot Analyzer and wind direction and wind velocity equipment.

The monitoring equipment in the trailer is to be completely replaced. Operational difficulties have been experienced with the existing equipment during the last several months. The SO_2 monitor and the H_2S analyzer are several years old. The Davis SO_2 instrument will be replaced with a Phillips SO_2 analyzer, generally accepted as the best on the market today. The A.I.S.I. instrument will be replaced with a newer model, complete with a recorder. The recorder enables one to have a permanent record of the reading, eliminating the problem of tape fading.

Attachment No. 9 tabulates the time SO_2 concentrations that were recorded for several levels of SO_2 concentrations. The total time that the SO_2 concentration exceeded 0.3 ppm was 11.75 hours. This is only three millionths of one percent of the total time since the D-1 Plant started up. It is pointed out that the high readings were all incurred before mid-1969, when sulphur recovery problems were experienced. Since that time, SO_2 concentrations have been below the acceptable limit. Attachment No. 10 graphically displays the highest H_2S concentration recorded each month. The reasons for the high readings are recorded on the graph. We cannot explain the high reading which occurred in October 1971. It is speculated that the cause is attributed to a well work.

In early 1972, the ERCB was concerned with a hill approximately two and one-half miles southwest of the Plant. According to their theoretical calculations, the hill could be subjected to approximately 0.6 ppm SO_2 concentration. Amoco Canada did not believe that the hill would be subjected to these concentrations as predicted by the Pasquill equation. Our calculations indicated that wind speed in excess of 20 m.p.h., wind direction from the north or northeast and overcast skies are required for the ground level SO_2 concentration to exceed 0.2 ppm. During a 21-month period in 1970 and 1971, the wind exceeded 20 m.p.h. for only 16 hours (0.106% of the time). The maximum wind speed obtained was 22 m.p.h. The wind direction from the north or northeast was only 16% of the time (0.0224% of the time combining the wind speed and direction). We do not maintain a record of the weather conditions but it can be seen that the probability of exceeding 0.2 ppm is extremely small. However, in March and April 1972, our continuous monitoring instruments were relocated to the top of this hill to actually record the SO_2 concentrations. In most cases, the readings obtained were zero. The highest reading obtained was April 12, 1972, when the concentration was 0.072 ppm. As a result of this test it was concluded that the hill was safe from potential SO_2 damage from the D-1 Plant.

3. Aerial Surveillance and Field Inspections

In the summer of 1970, the first infra-red aerial photography survey was conducted around the East Crossfield Plant area. The survey covered an area between 30 to 40 square miles. The infra-red film is very sensitive to the presence of chlorophyl in living plants and any stress to the plants can be detected long before the stress is noticeable to the naked eye. The stress may be caused by natural causes, such as poor water drainage, high alkalinity in the soil, poor soil cultivation techniques, etc., or from industrial causes such as SO_2 or elemental sulphur from the D-1 Plant. The exact cause of the stress can only be determined by field investigations.

The 1970 infra-red survey and a soil survey indicated no vegetation stress as a result of the D-1 operation except immediately around the sulphur block. As described in the "Problems Encountered" section, the soil exhibited an increase in acidity. The infra-red aerial photography survey was again repeated in 1971. During 1972, the infra-red and soil surveys were again repeated together with a vegetation survey. The last soil survey included an acidity test, sulphur content, migration of the sulphur into the soil and the amount of corrective measures required to return the soil to its original acidity.

The 1972 survey report has not yet been finalized, however, initial inspections of the data indicate similar results as previous 1970 and 1971 surveys. The spread of the soil acidity around the sulphur block now appears to be arrested. This is attributed to the use of the sulphur slating facilities. Also in 1972, the use of COSPEC (Correlation Spectrometer), supplied by ERA Instruments is being used in an attempt to determine the downwind stack plum pattern and airborne pollutant concentrations.

4. Sulphur Dust Fall

There are twelve sulphur dust fall cylinders now installed around the sulphur block area to minitor the volume of sulphur dusting. The cylinders consist simply of a 48-ounce plastic jar mounted on a post. They are located between 1/8 to 1 mile radius of the Plant site as shown in Attachment No. 6. To date, no standard has been established for sulphur dusting conditions nor is one required, since with the installation of the sulphur slating facilities in 1971, sulphur dusting is no longer a problem.

5. Reporting Procedures

Every month, a report is forwarded to the Department of the Environment and to the ERCB summarizing the result of the previous month's monitoring. During the daily operation if any readings exceed the air quality control standard, the situation must be reported immediately by telephone and confirmed by letter. The information must include hourly averages and peak readings, wind direction and velocity, probable cause and corrective actions taken. This data must also be included in the monthly report. Also, any reading exceeding 0.05 ppm SO_2 and 0.003 ppm H_2S must be reported in detail in the monthly report, with probable reasons for the high readings.

Every three months, the Conservation Board requires a stack survey. An independent laboratory is contracted to perform this service. The survey involves measuring the emission from the stack and obtaining a velocity profile. We attempt to run a sulphur plant performance test on the same day to measure our sulphur plant efficiency and to correlate our pollution monitoring methods.

L. Future Outlook

In November 1971, the ERCB issued Informational Letter IL 71-27 which indicated more stringent sulphur recovery levels for various sizes of sulphur plants. The Board issued the letter having "considered the matter of appropriate sulphur conservation requirements on the basis of current technology and the economics of sulphur recovery and, bearing in mind its responsibilities respecting pollution control". For the East Crossfield D-1 Plant, the sulphur recovery must be increased fromthe present 96% level to 98.2%.

A study was made of available tail gas cleanup processes, its investment and operating costs. Attachments No. 11 and 12 tabulates the investment and operating costs of tail gas cleanup processes to achieve 98% and 99% recovery levels. The study indicated that the most economical process at this time will cost about $2,700,000 to achieve 98% sulphur recovery efficiency and about $4,100,000 to achieve 99% sulphur recovery efficiency.

The operating cost for a 98% recovery process will be $566,000 per year. This estimate includes electric power cost of $115,000 per year and steam power cost of $5,000 per year for a total energy cost of about $120,000 per year.

The incremental 2% sulphur recovery will be approximately 32 long tons per day (11,000 long tons per year). The current sales price of sulphur is about $6 per long ton (F.O.B. Plant) and about 60% of Alberta sulphur is being sold. The 11,000 long tons per year sulphur is worth $66,000 per year if all of the sulphur is sold.

It becomes exceedingly difficult to comprehend the requirement of conserving $66,000 worth of a sulphur resource at an expense of $120,000 per year of another more valuable natural resource, particularly when our pollution monitoring data indicates more stringent sulphur recovery levels are not required. Moreover the investment and other operating costs have not been taken into consideration.

It is similarly true in the case of the 99% sulphur recovery level. Forty-eight long tons per day (17,420 long tons per year) of additional sulphur will be recovered which is valued at $103,520 per year at $6 per long ton if all of the recovered sulphur is sold. The steam and electric power cost to recover the incremental 3% of sulphur is $131,000 per year.

Inflationary and unforseen costs have placed a cost squeeze on the D-1 project. In 1967, we entered a project based on $33,245,000 initial investment, $5,800,000 of delayed investment for a total cost of $39,045,000. The estimated annual operating cost was $2,184,000. In actuality, $36,000,000 was initially invested with a projected $15,800,000 of delayed investment for a total of $51,800,000. This is $18,555,000 more than anticipated. In addition, the operating cost has been $2,321,000 per year which is $137,000 per year greater than forecasted. The sulphur sales price was estimated to be $30 per long ton rather than the present $6 per long ton. At the time the project was approved, there was no conception of more stringent sulphur recovery limitation would be imposed on this project.

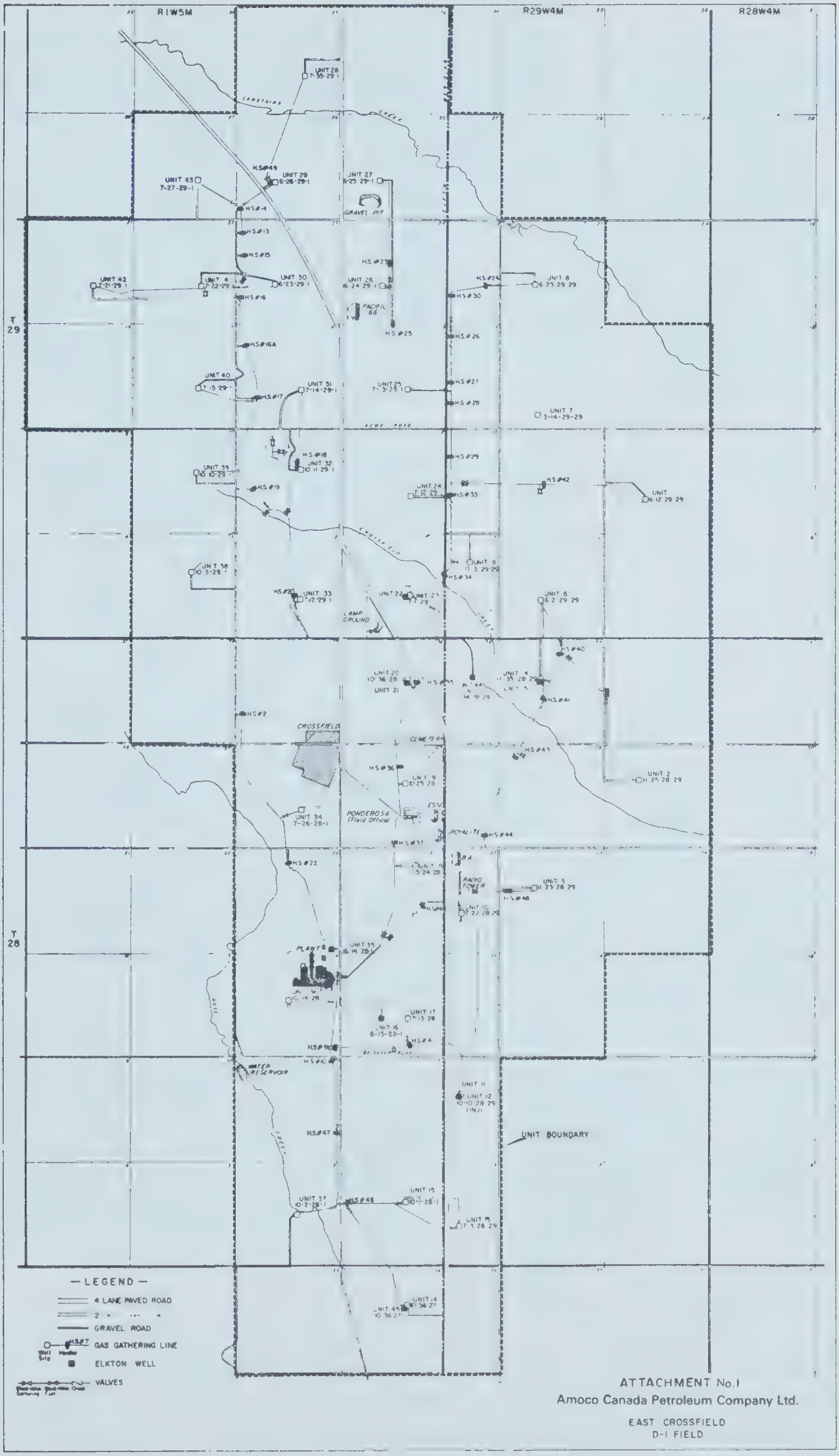
We are hopeful that a gas price increase will be realized. However, about 50% of the gas reserve in the D-1 reservoir are covered by a contract which does not contain a sales gas price redetermination clause. The remainder of the reserves do contain a price redetermination clause. As a result, any sales gas price increase which might come about, the effect on the D-1 project may not be substantial. Any governmental actions such as increased royalty, application of more stringent air pollution regulations, the installation of a tail gas cleanup process, could impose an additional burden on the project to a point that continued operation of the project may not be economic.

Amoco Canada wholeheartedly supports the establishment of reasonable and justified regulations for the protection of the environment. Our activities at East Crossfield in particular and in Alberta in general, reflect our sincere desire to continually improve gas processing technology and we have, in fact, contributed to the advancement of the industry. Obviously the benefits of the oil and gas industry to the people of the province through employment, royalties and taxes are also of great importance. We recognize the pressures of some parties for absolute environmental preservation, but we believe that there must be firm evidence of need to justify restrictions which will stifle and perhaps destroy portions of Alberta's economy.

Insofar as East Crossfield operation is concerned, we respectfully submit that existing requirements be continued so long as the present surveillance and surveillance through future advanced technology indicates no adverse effect on the environment of the area.

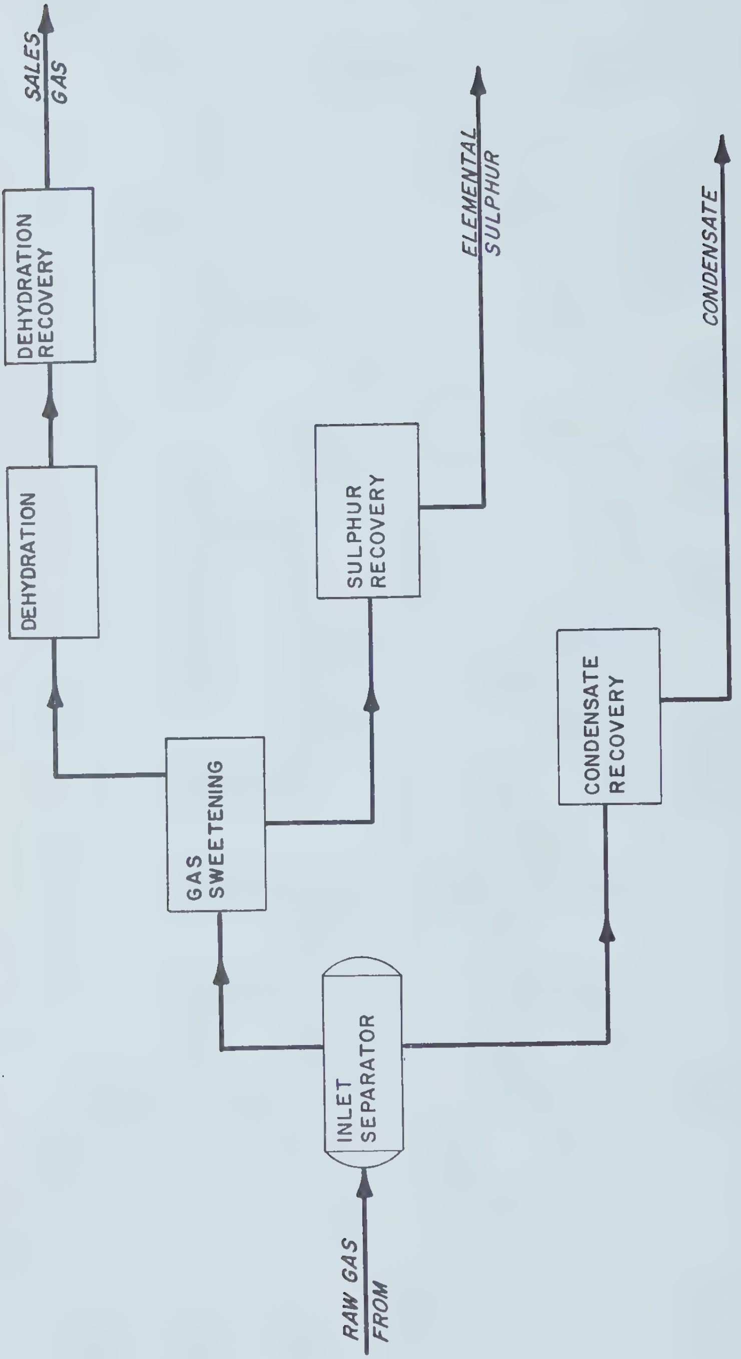
M. List of Attachments

1. Map
2. Simplified Plant Flow Diagram
3. Aerial Photograph
4. Sulphur Recovery Efficiencies
5. Notification Card
6. Location of Exposure Cylinders and Dustfall Cylinders
7. Exposure Cylinder Results by Amoco Canada
8. Exposure Cylinder Results by the Department of the Environment
9. SO_2 Monitoring Data
10. H_2S Monitoring Data
11. 98% Tail Gas Cleanup Processes
12. 99% Tail Gas Cleanup Processes

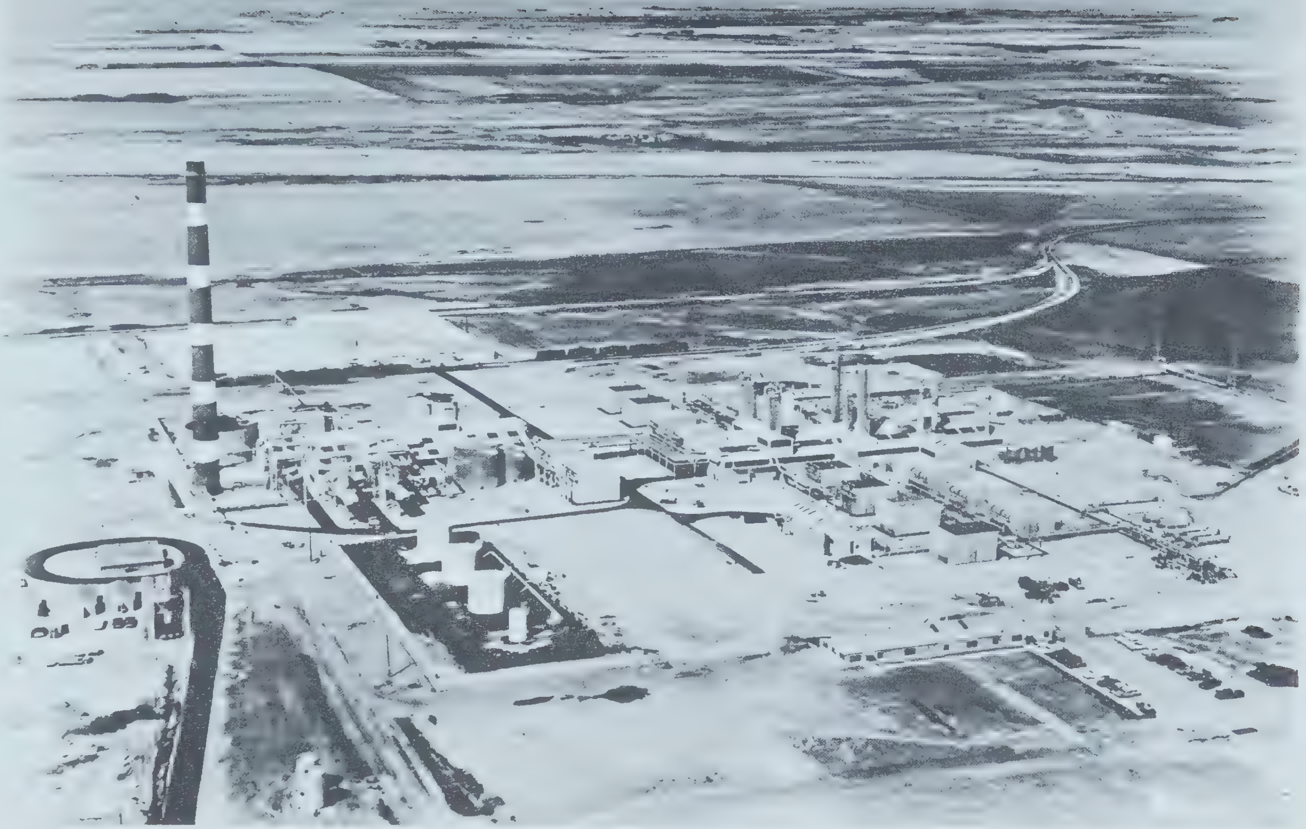


ATTACHMENT No.1
Amoco Canada Petroleum Company Ltd.

EAST CROSSFIELD
D-1 FIELD

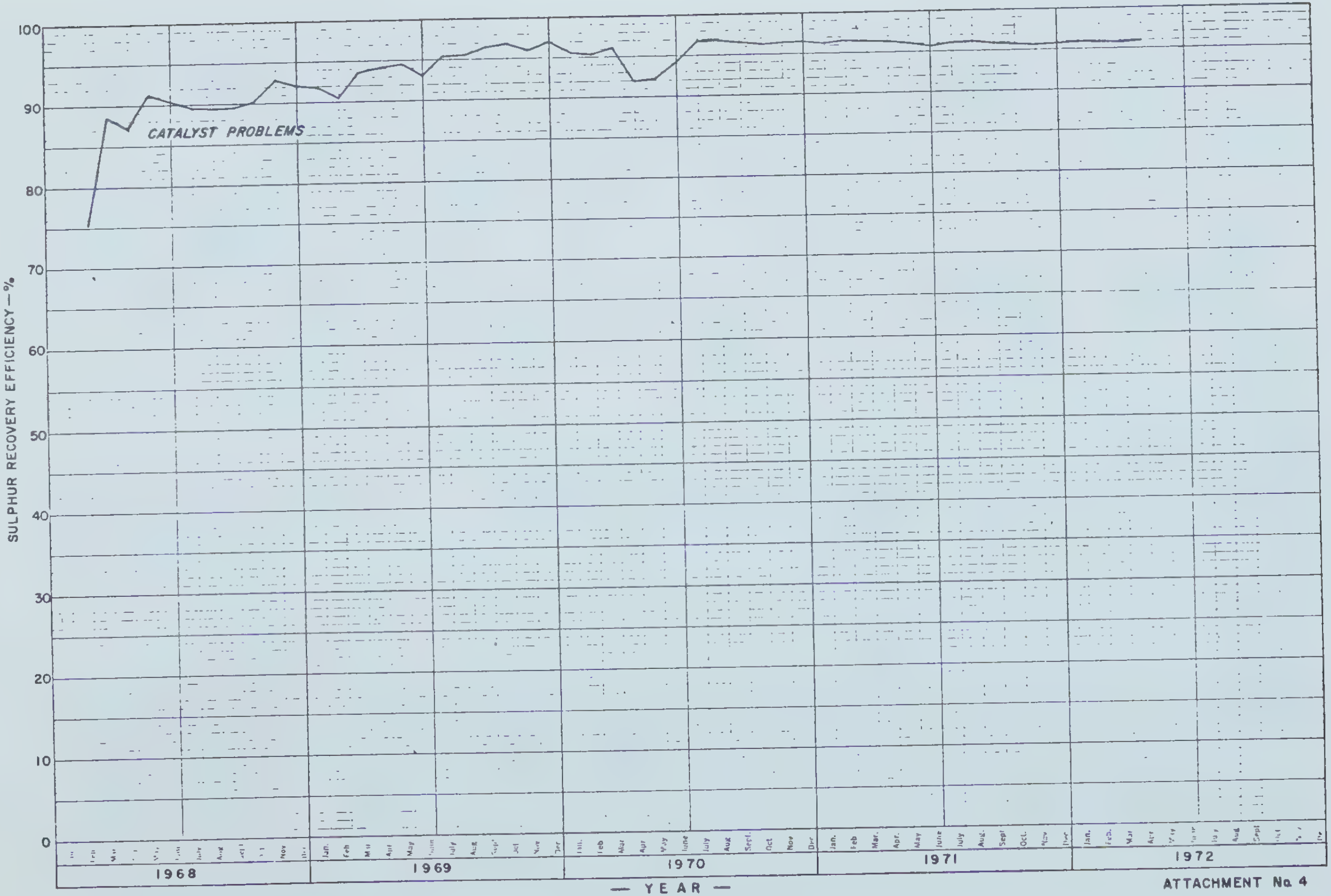


SIMPLIFIED FLOW DIAGRAM
EAST CROSSFIELD D-1 PLANT
ATTACHMENT No. 2



ATTACHMENT No. 3

EAST CROSSFIELD D-1 PLANT
SULPHUR RECOVERY EFFICIENCIES



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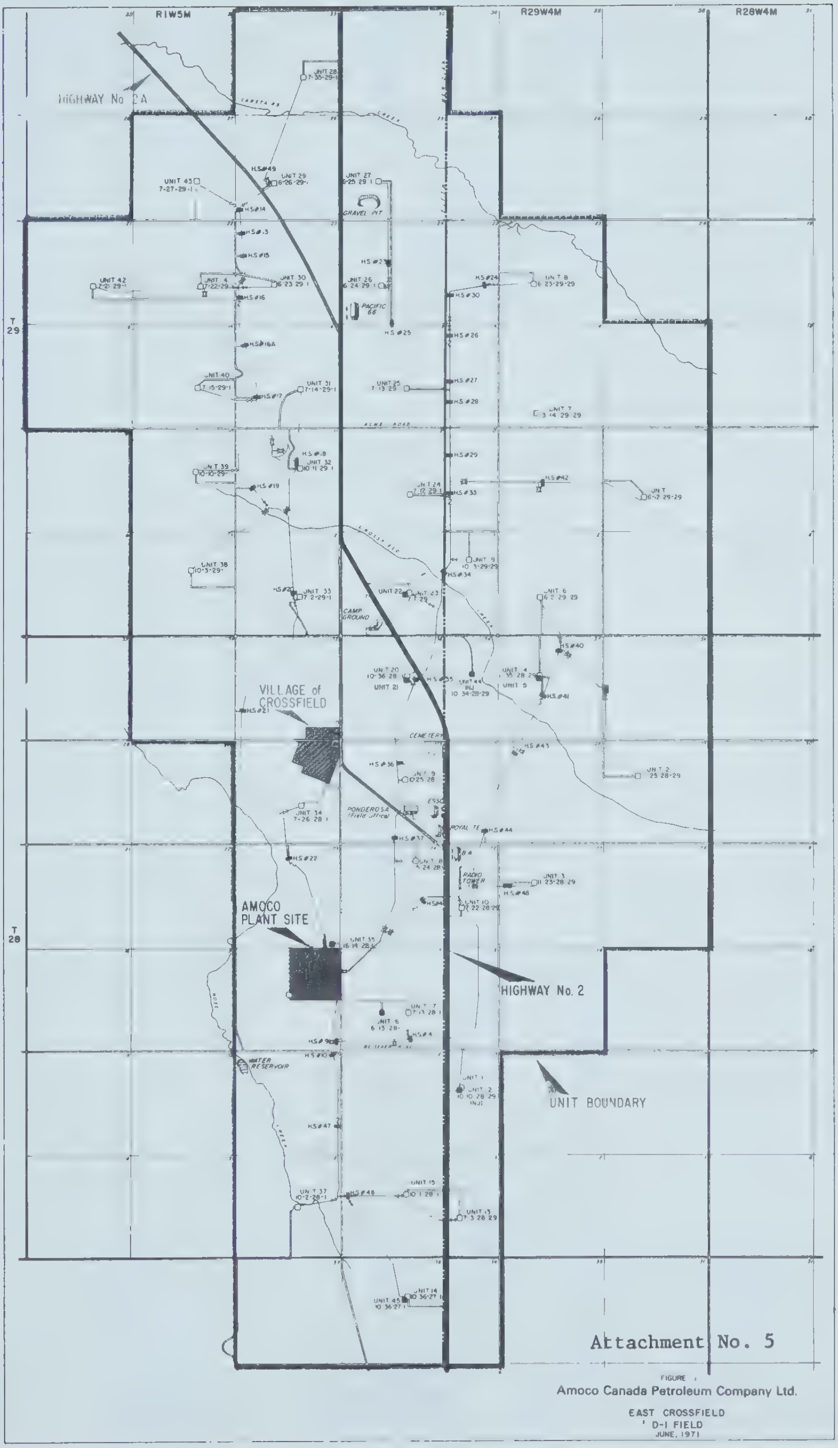
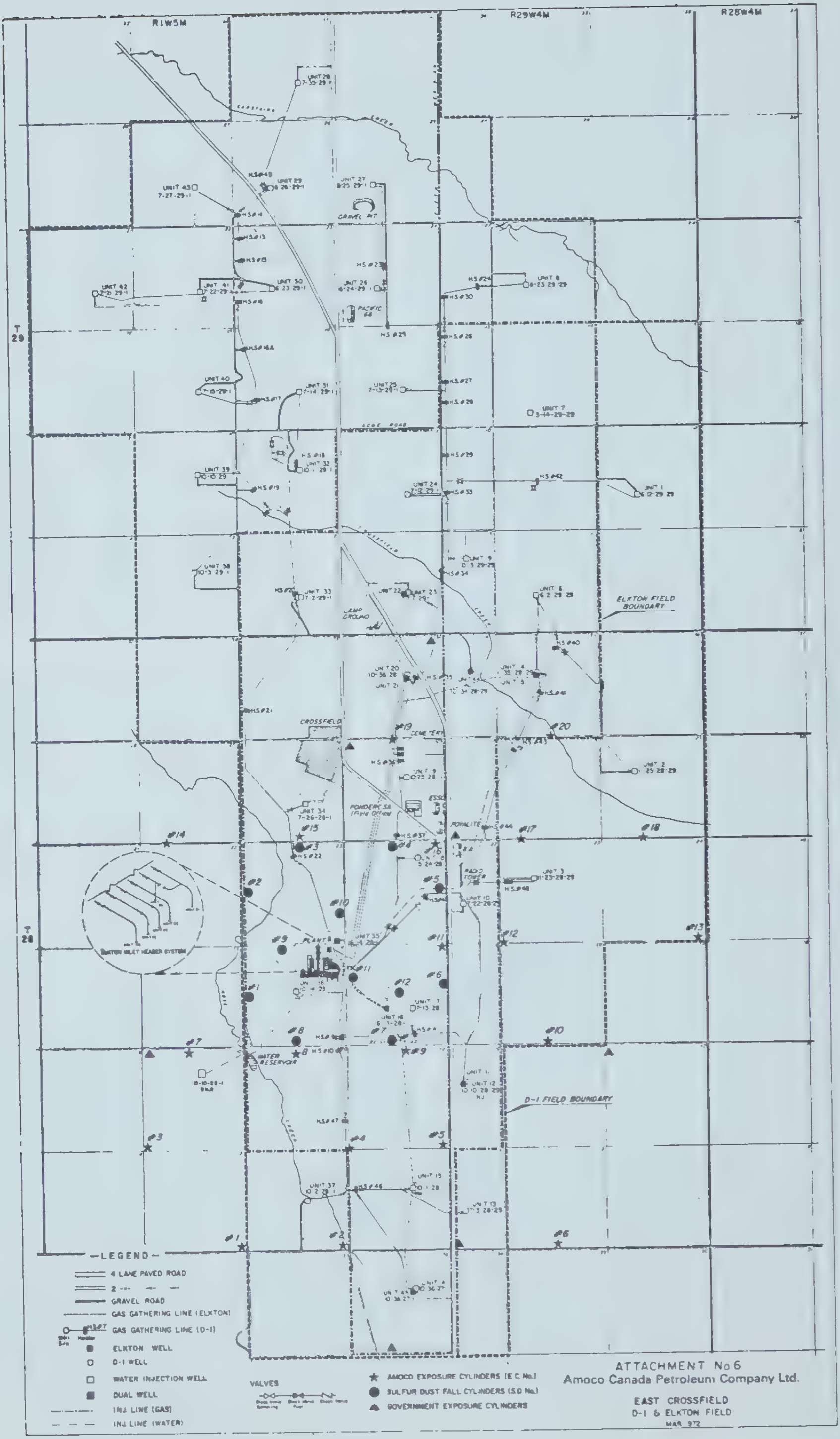


Attachment No. 5

FIGURE

Amoco Canada Petroleum Company Ltd.

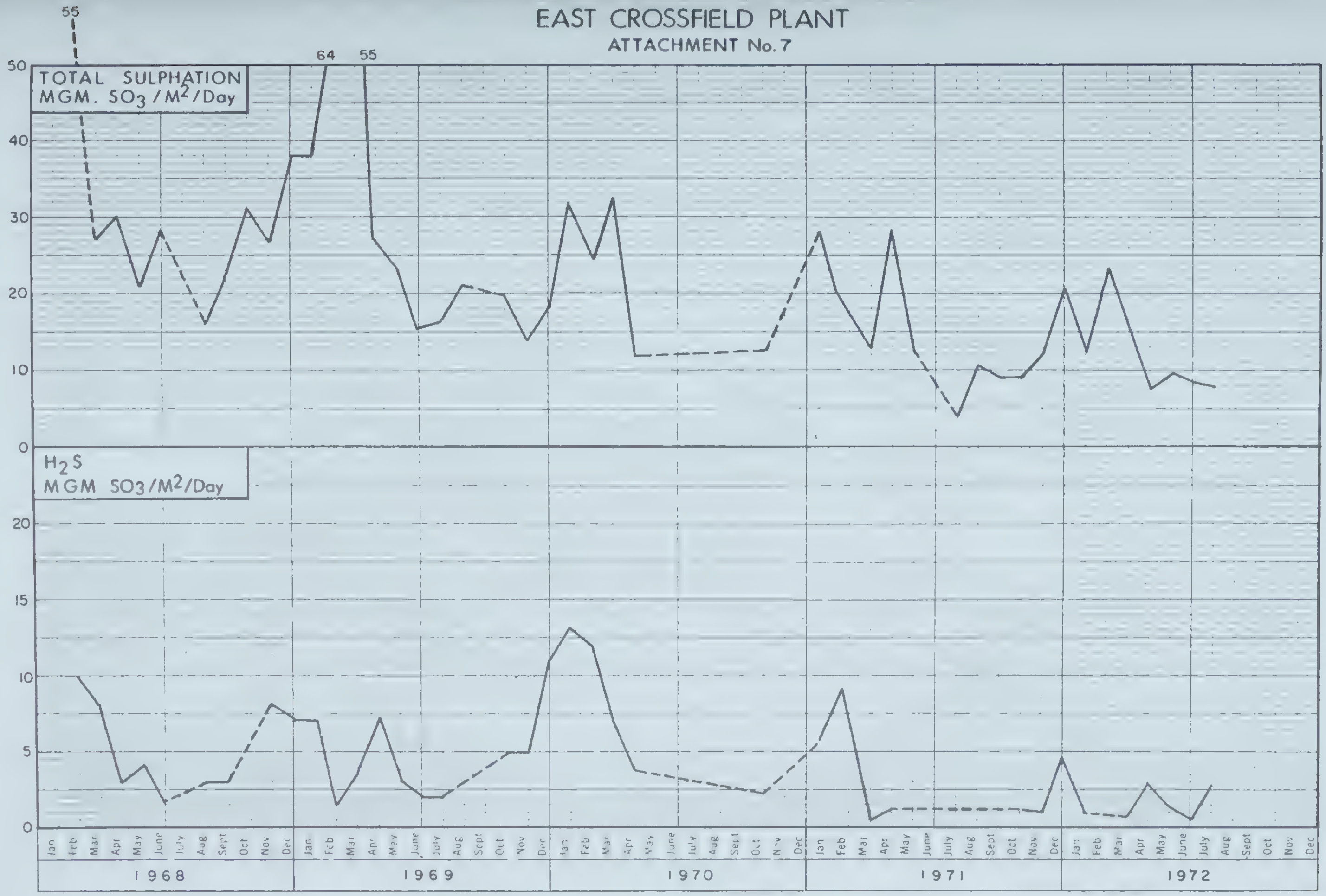
EAST CROSSFIELD
D-1 FIELD
JUNE, 1971



ATTACHMENT No 6
Amoco Canada Petroleum Company Ltd.

EAST CROSSFIELD
D-1 & ELKTON FIELD
MAR 972

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT
ATTACHMENT No. 7

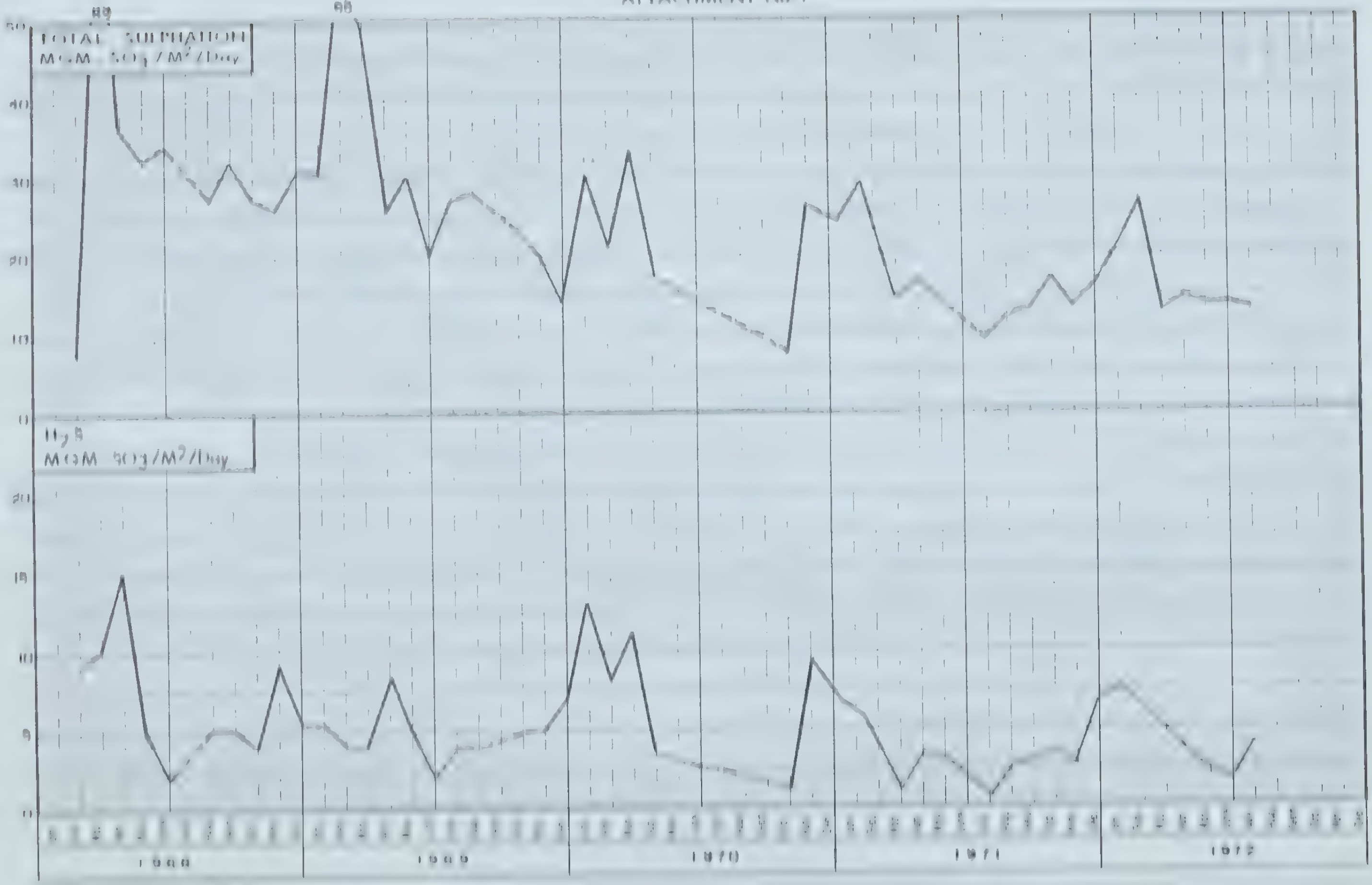


STATION No. 1

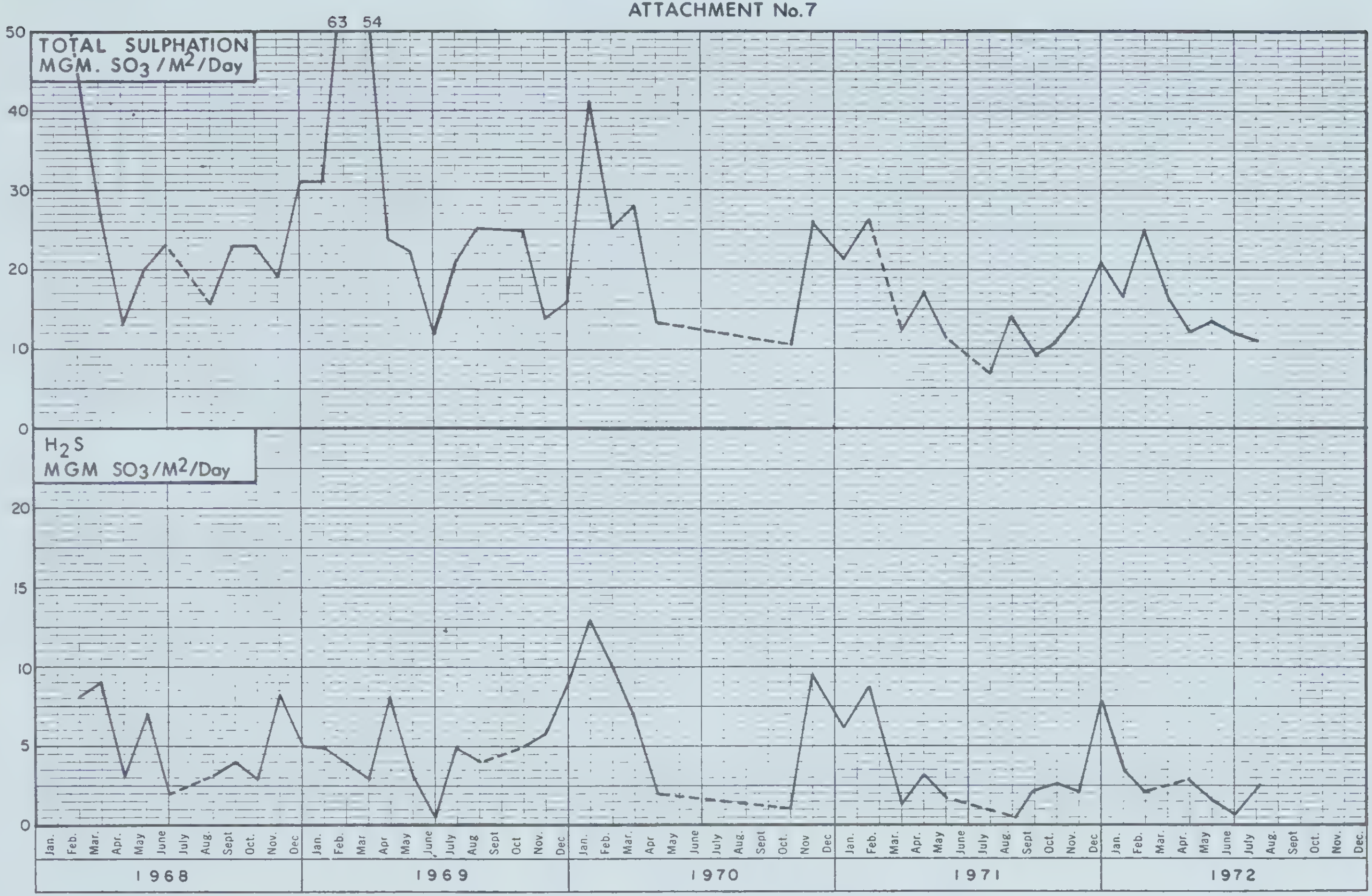
Amoco Canada Petroleum Company Ltd

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No. 7



ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT
ATTACHMENT No.7

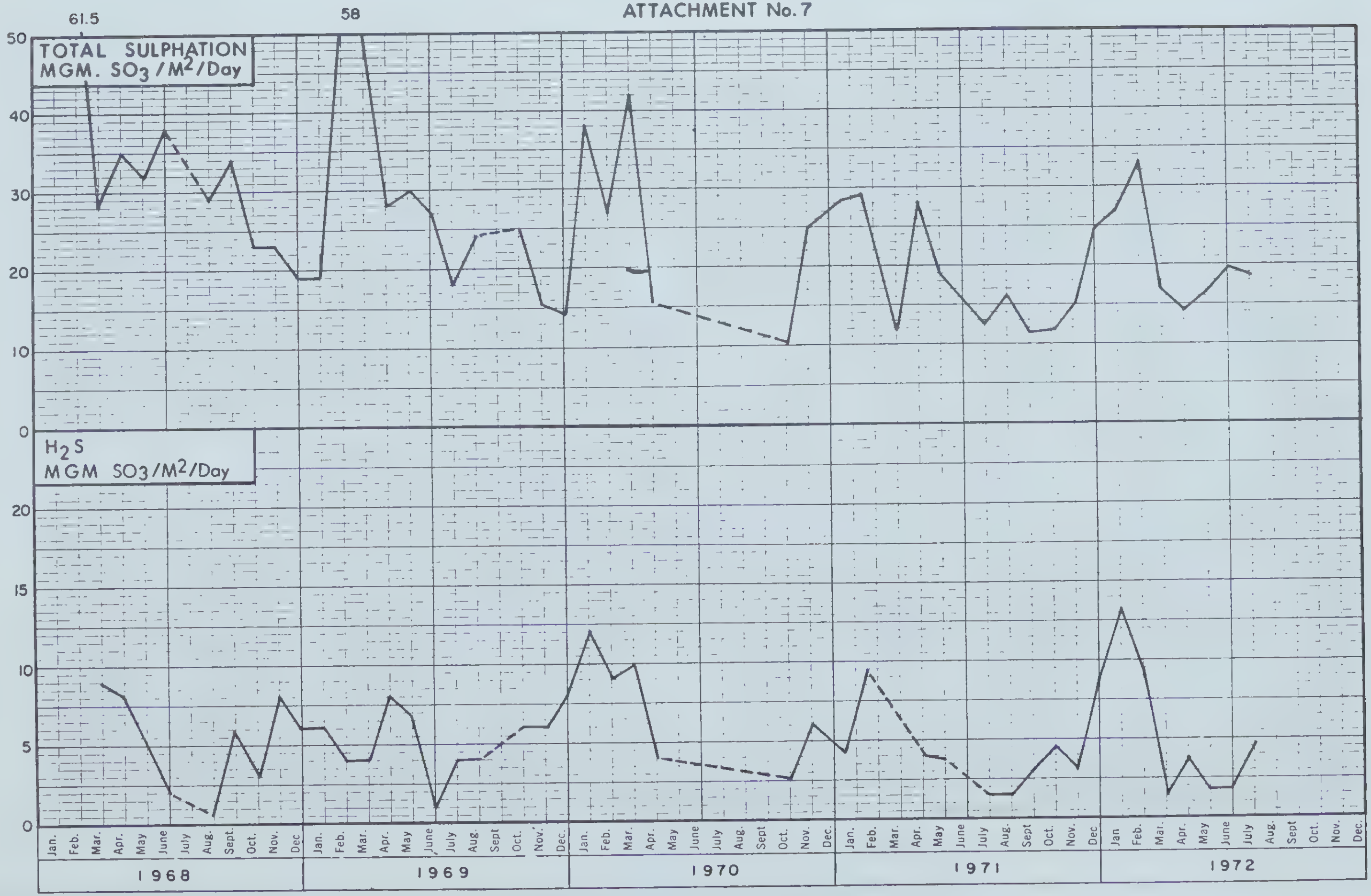


STATION No. 3

Amoco Canada Petroleum Company Ltd.

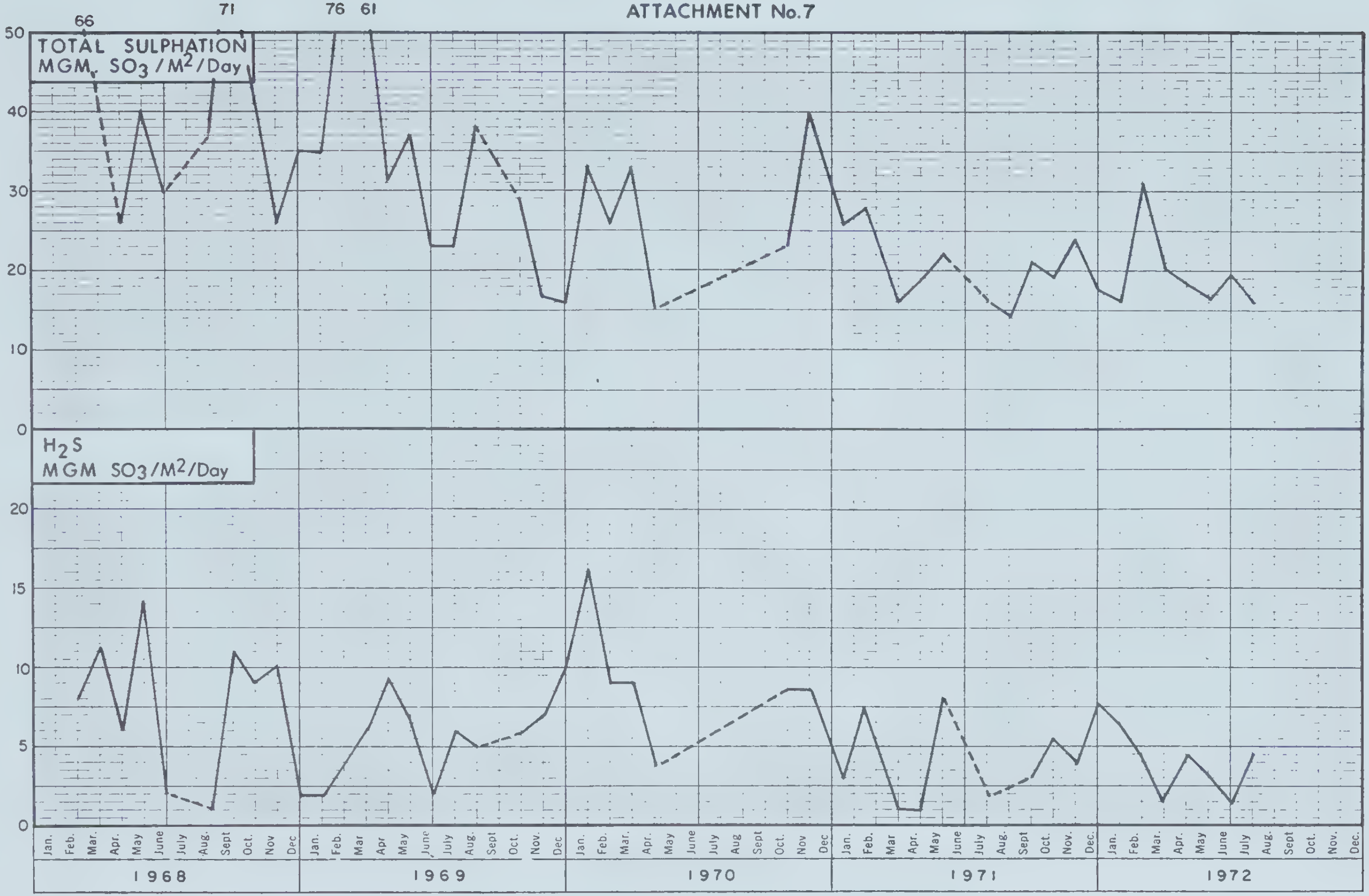
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No. 7



ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7

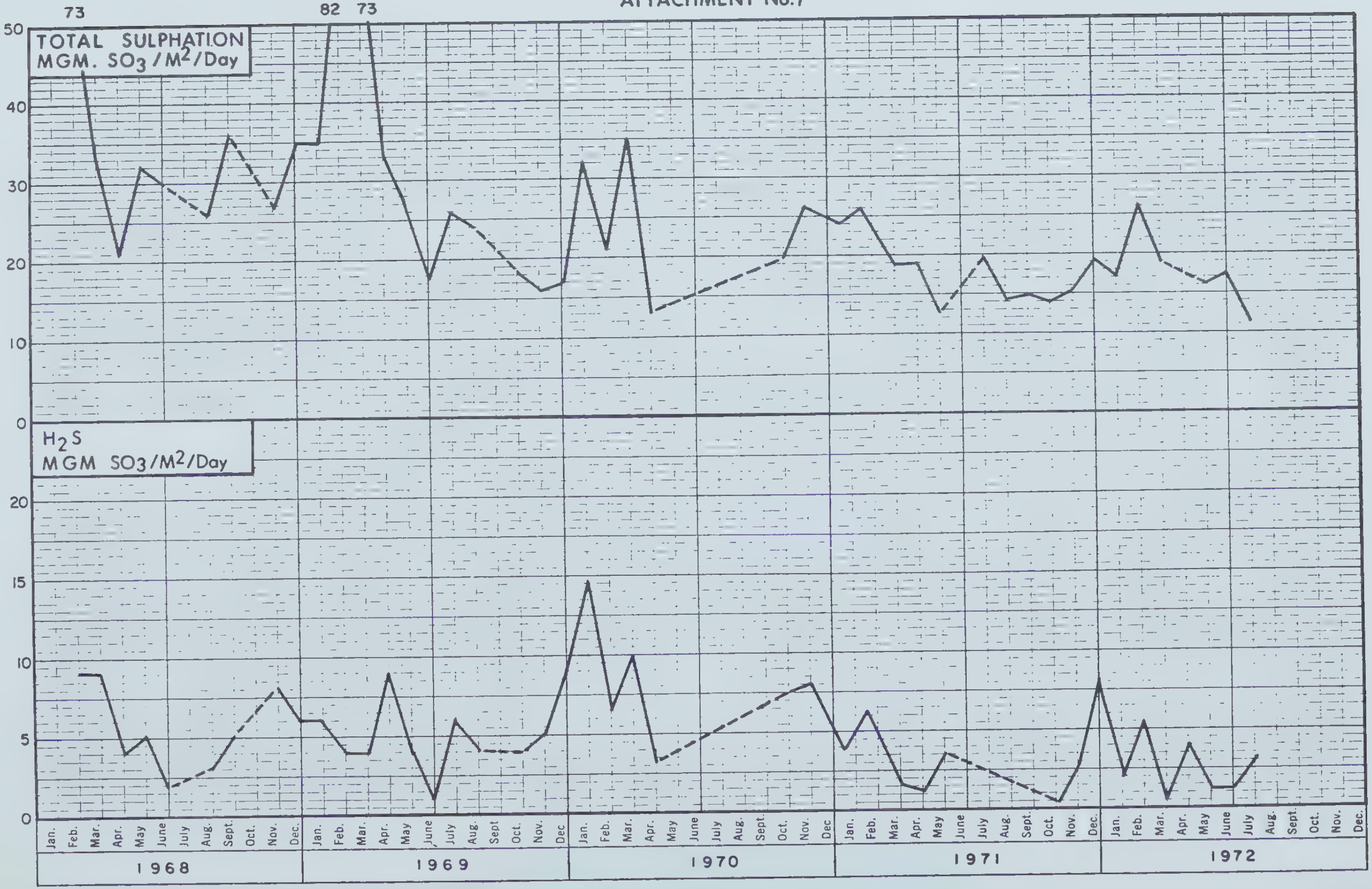


STATION No. 5

Amoco Canada Petroleum Company Ltd.

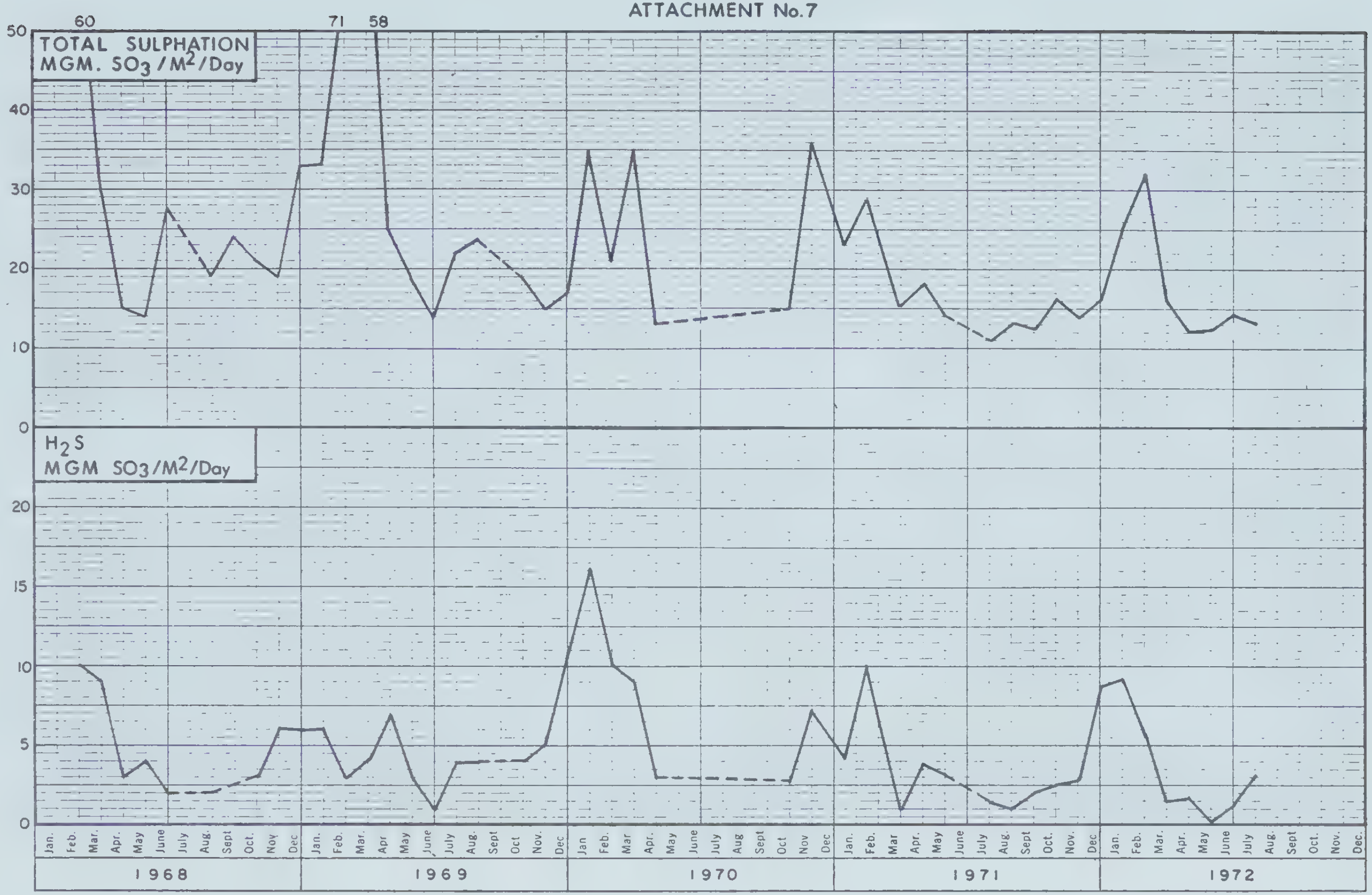
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7



ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No. 7

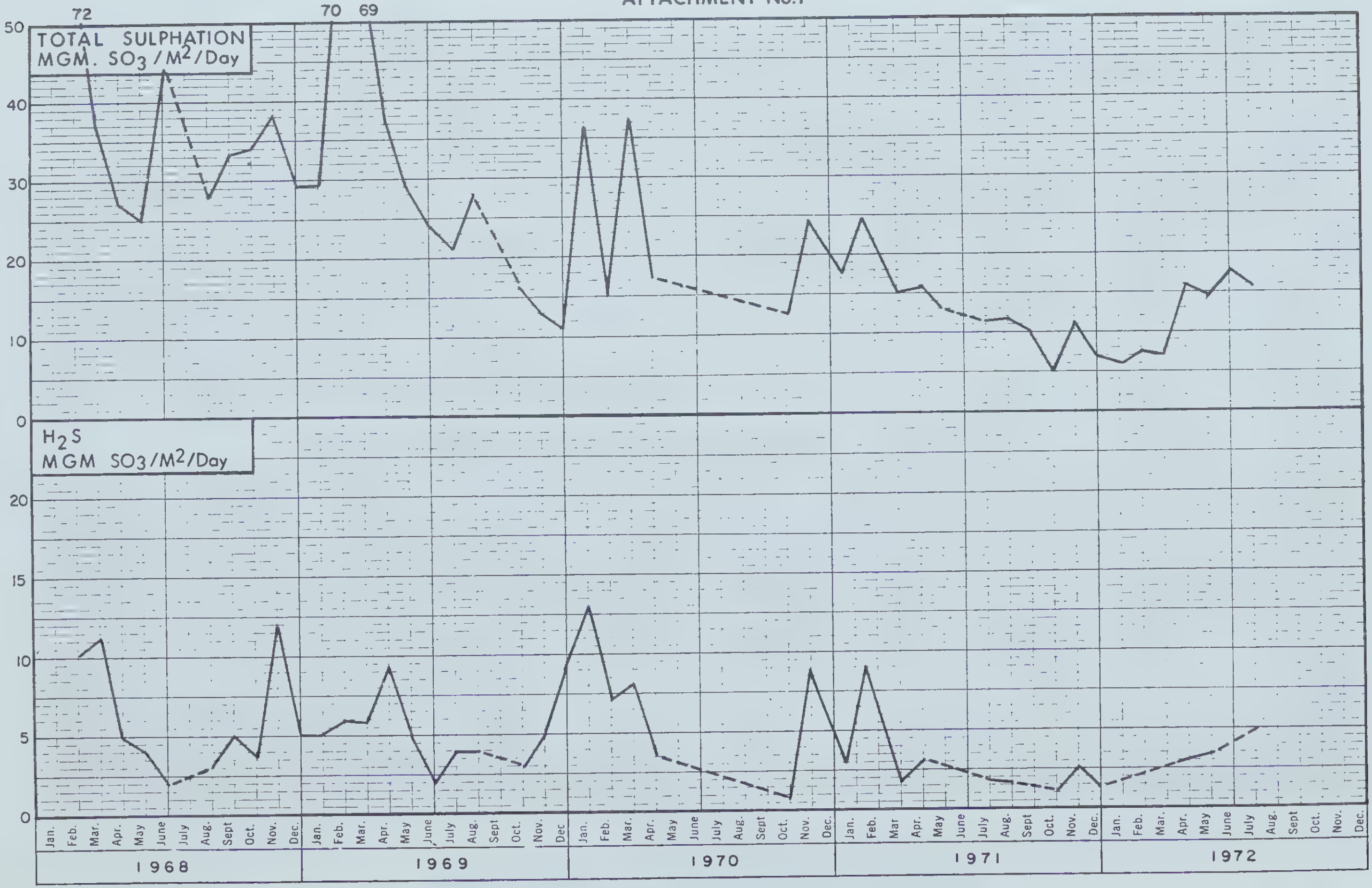


STATION No. 7

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

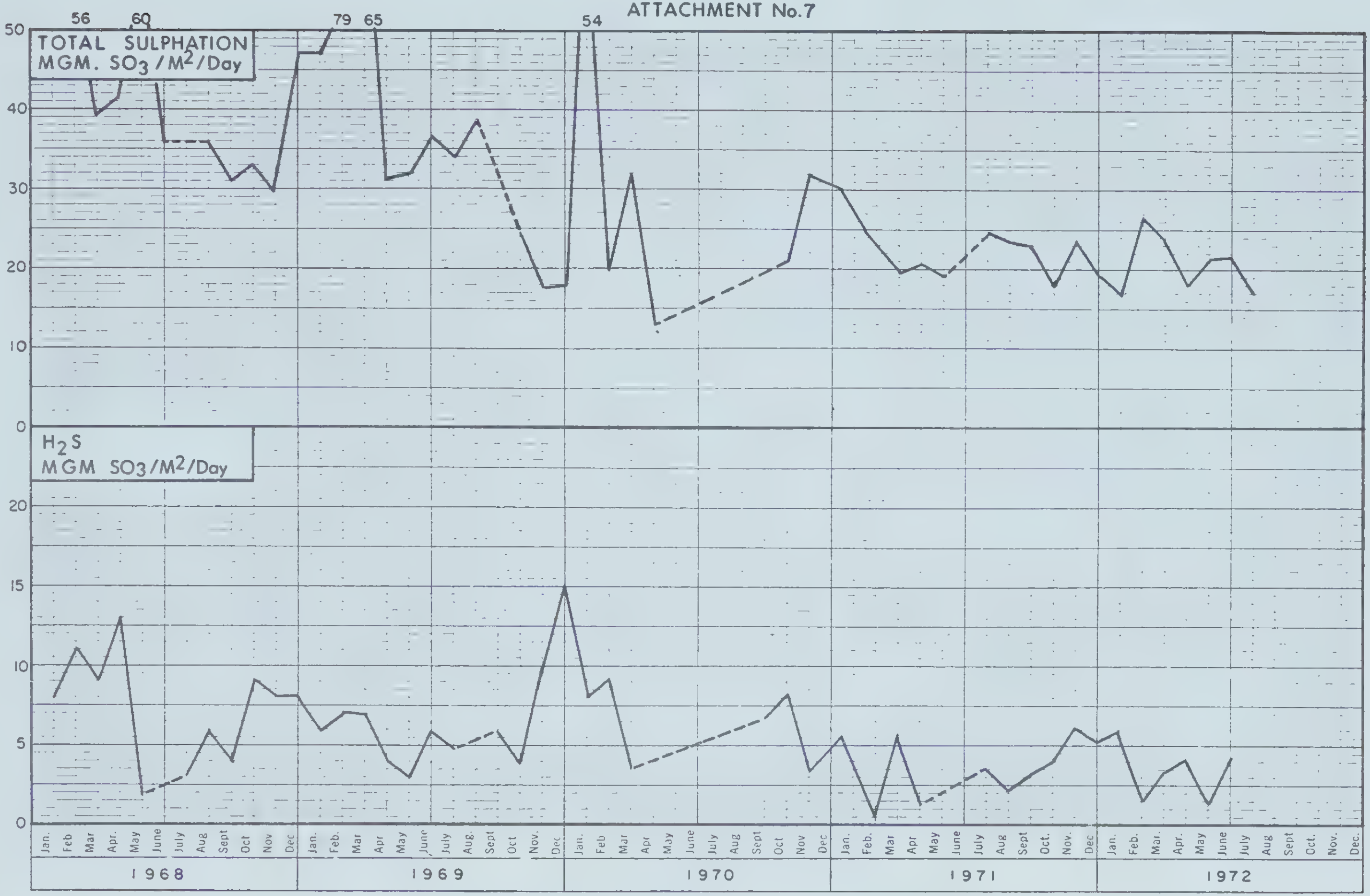
ATTACHMENT No.7



STATION No. 8

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7

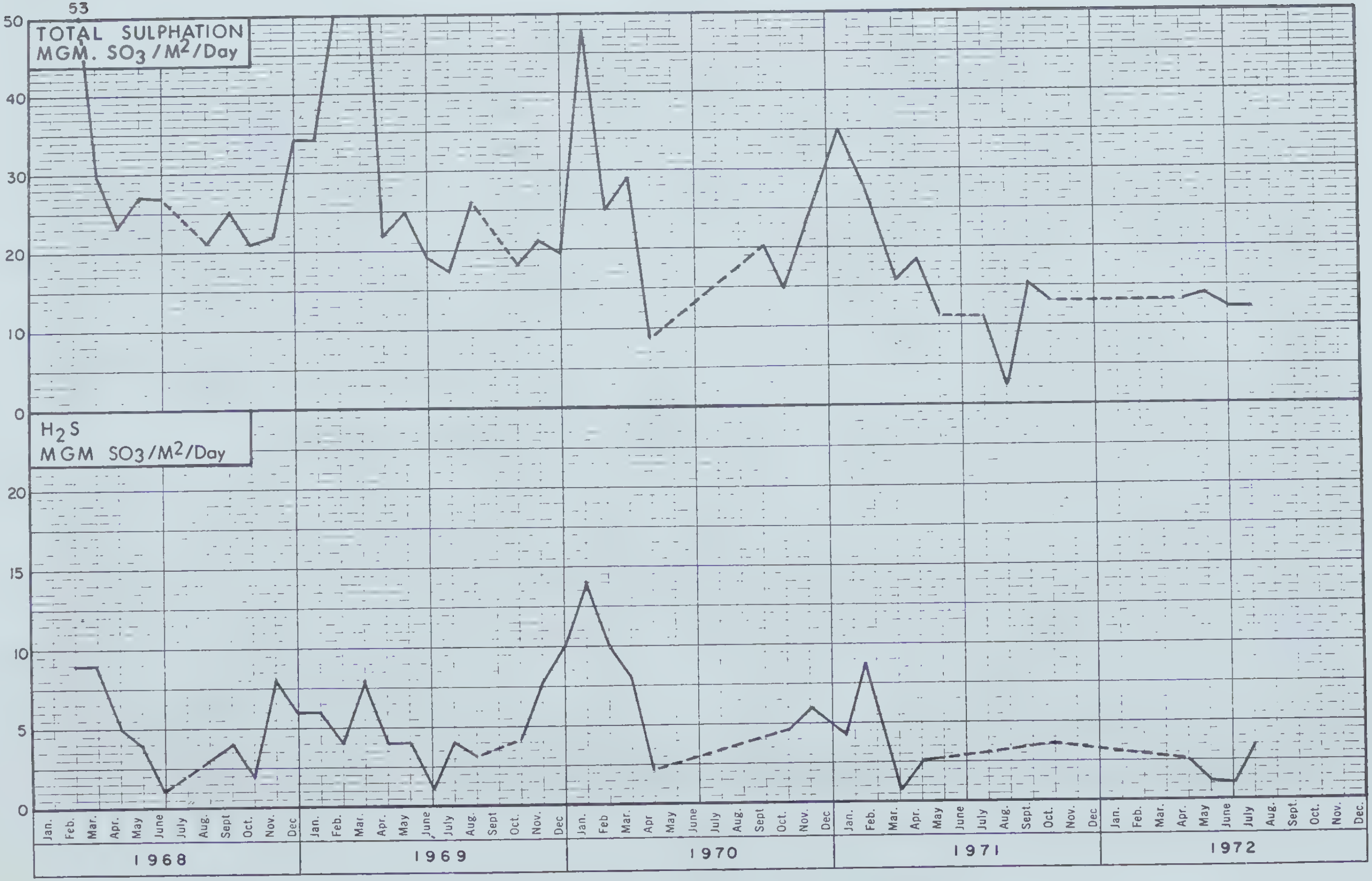


STATION No. 9

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7



STATION No.10

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

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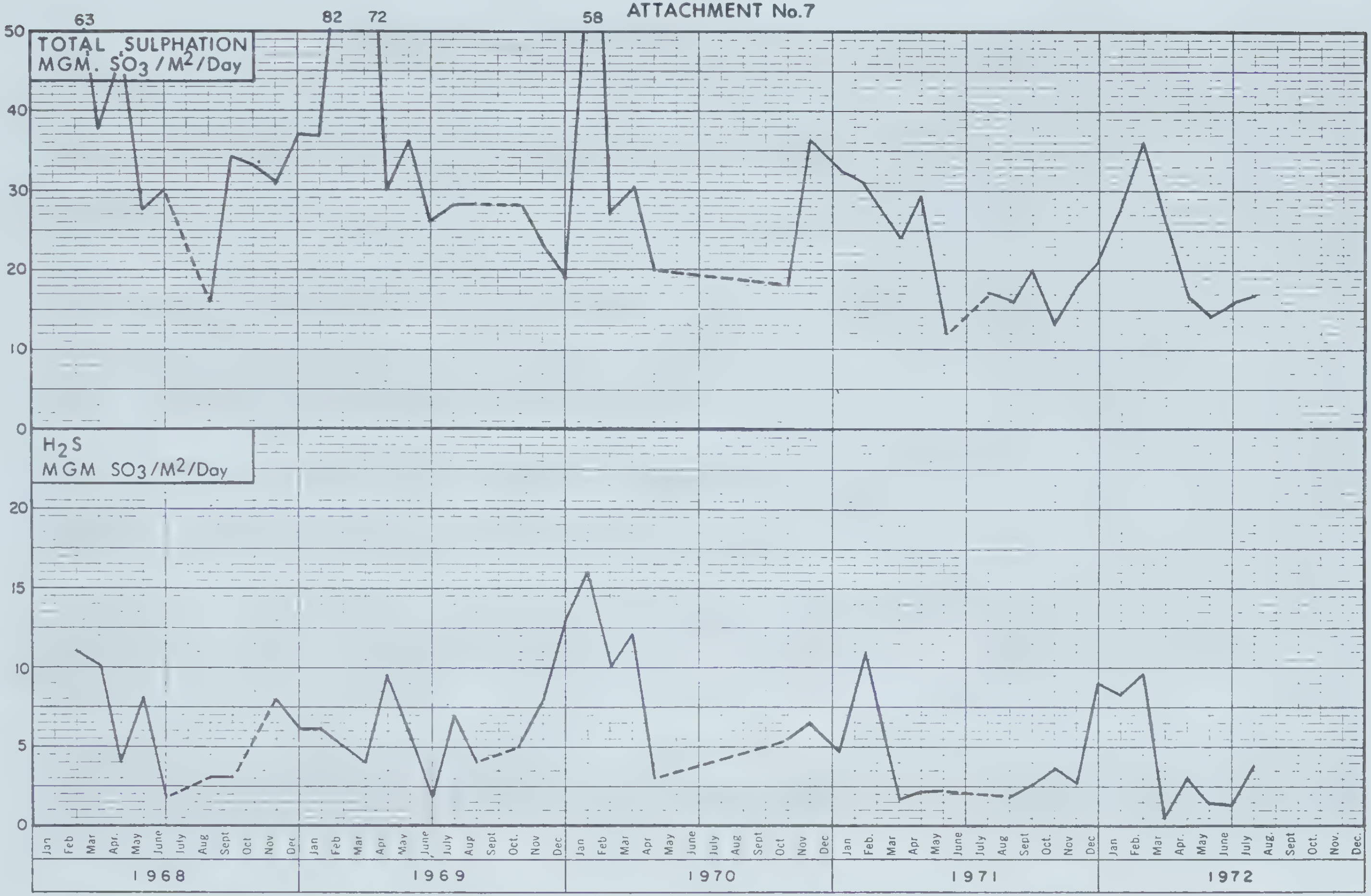
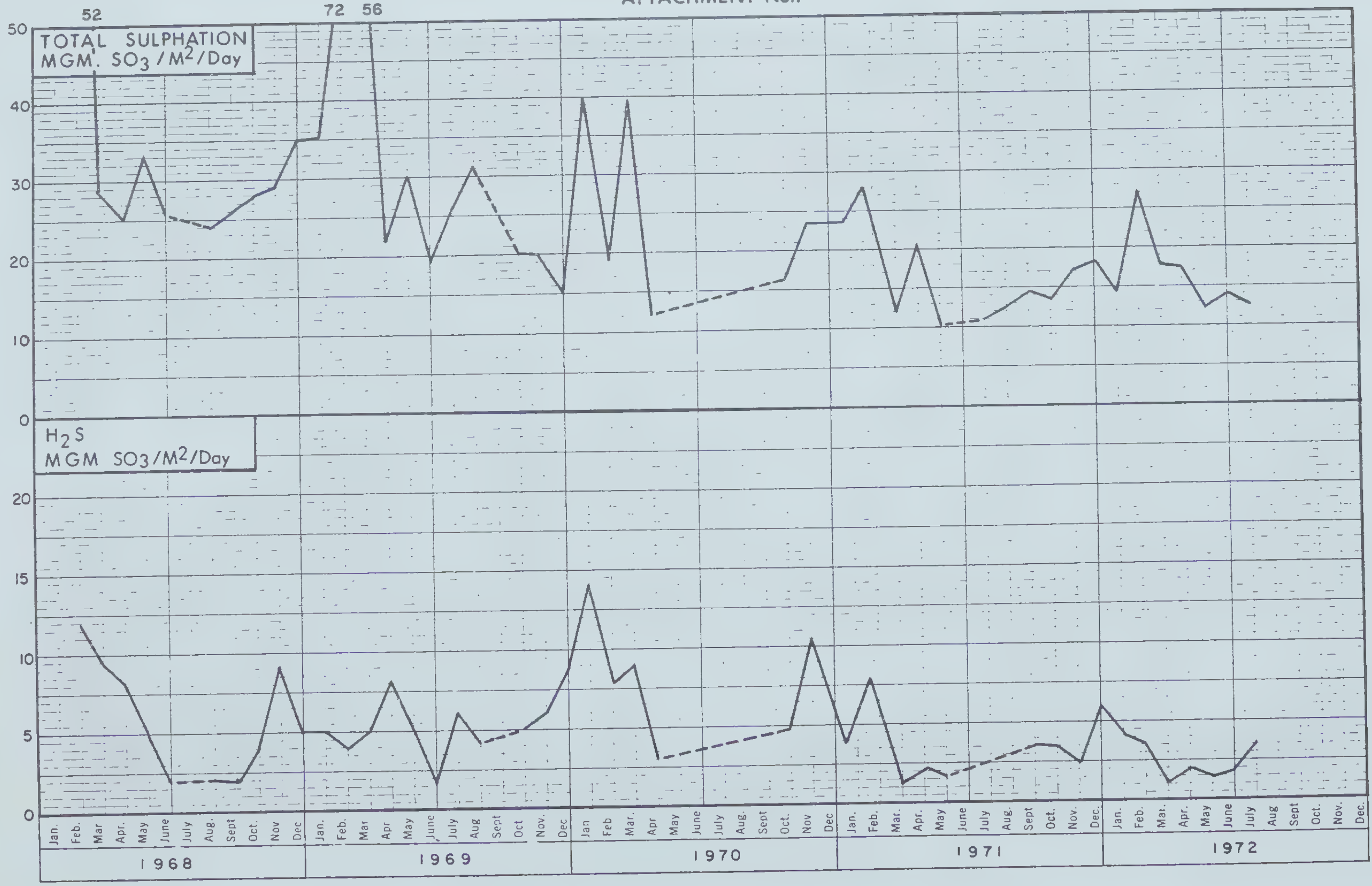


STATION No. 11

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

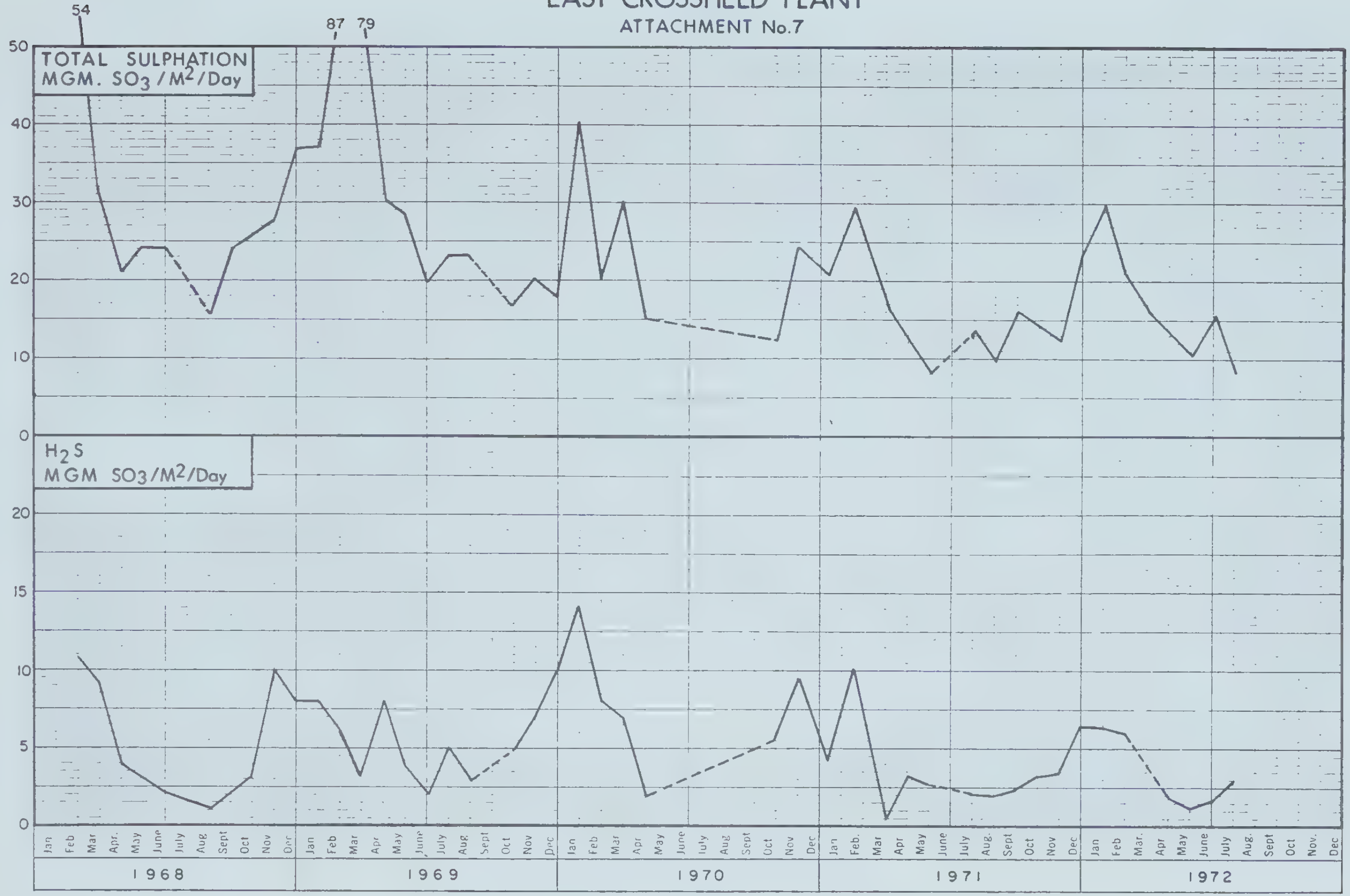
ATTACHMENT No.7



STATION No. 12

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7



STATION No. 13

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

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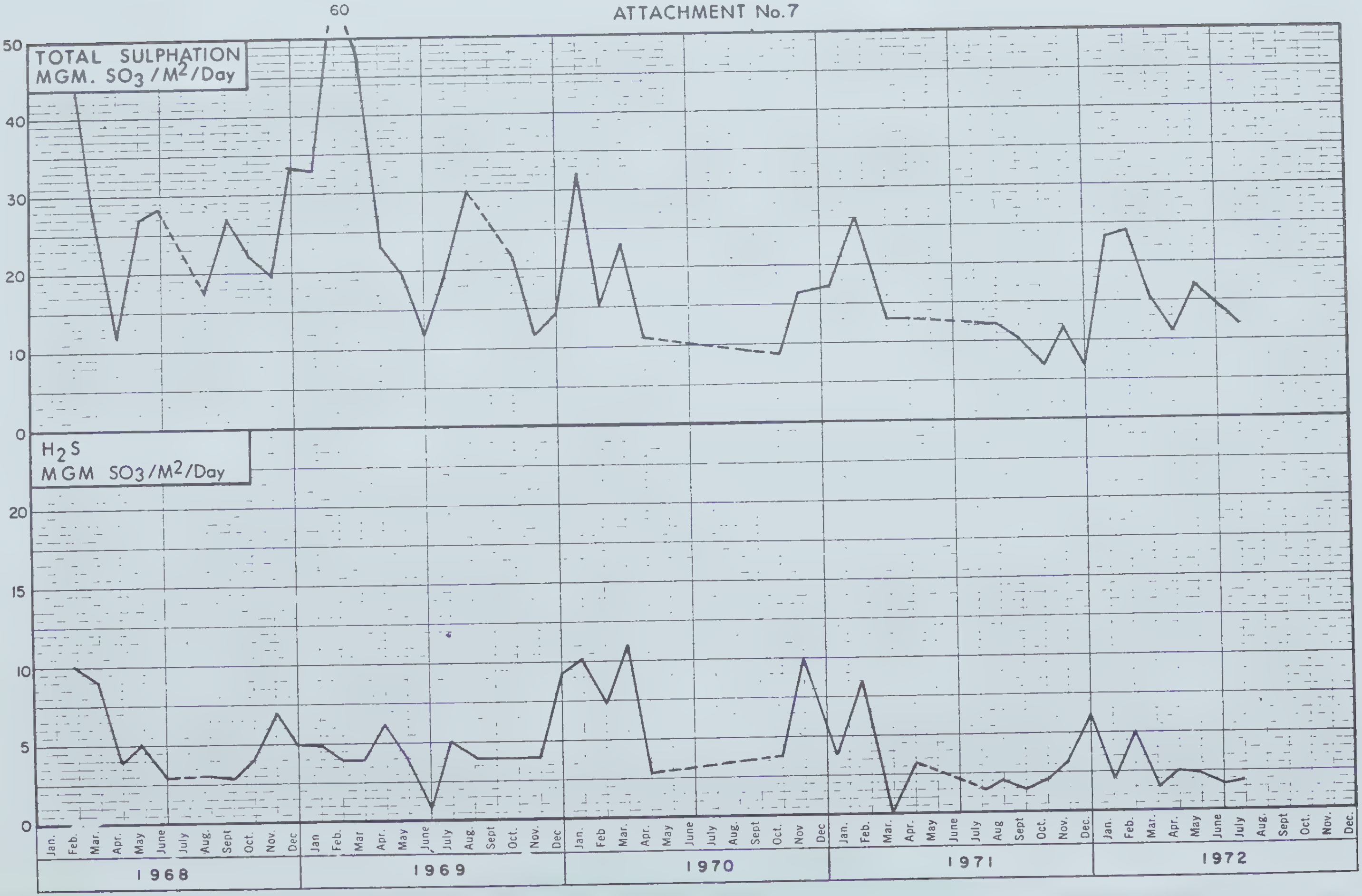
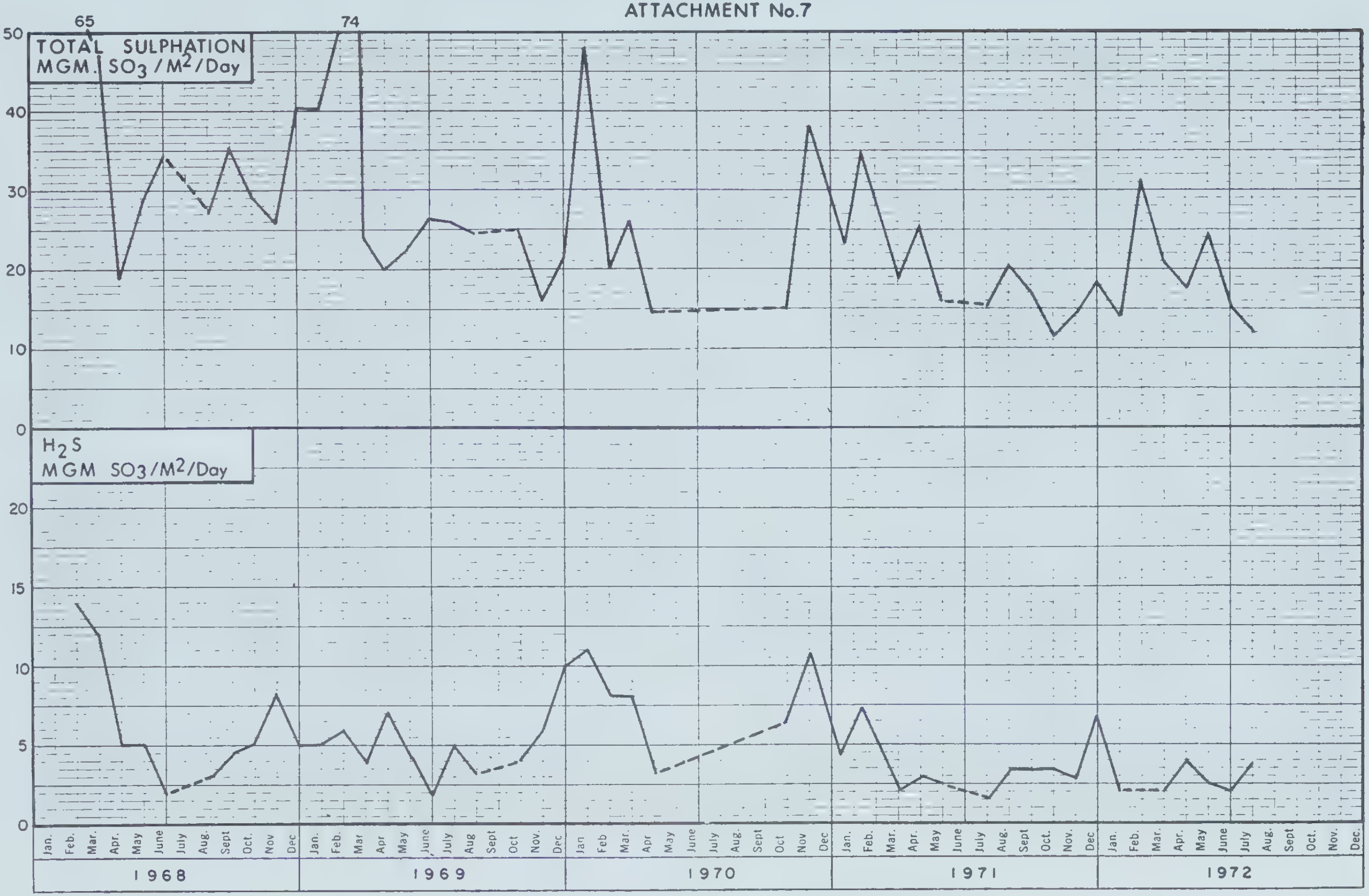


STATION N 14

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT
ATTACHMENT No.7

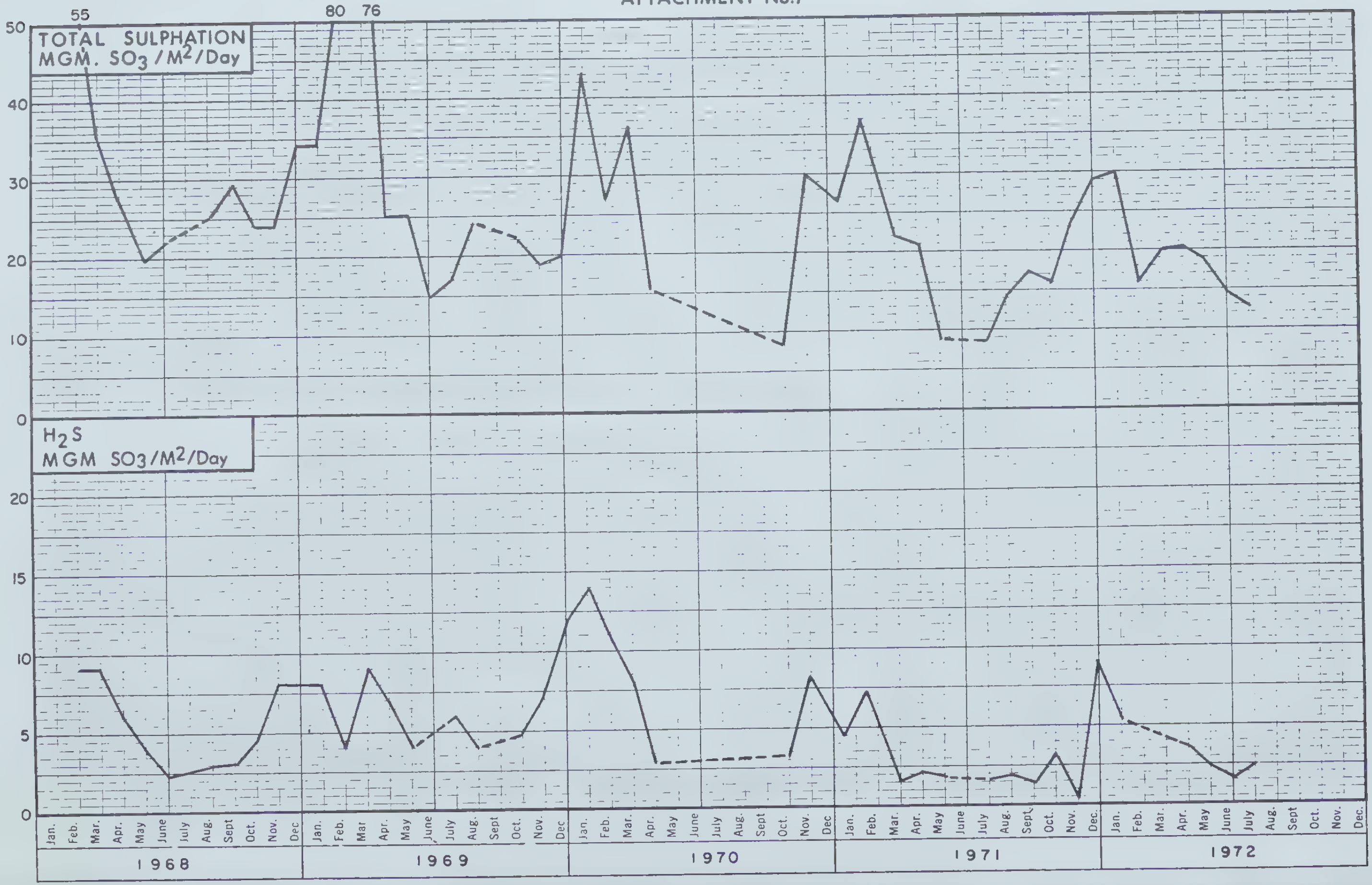


STATION No. 15

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7



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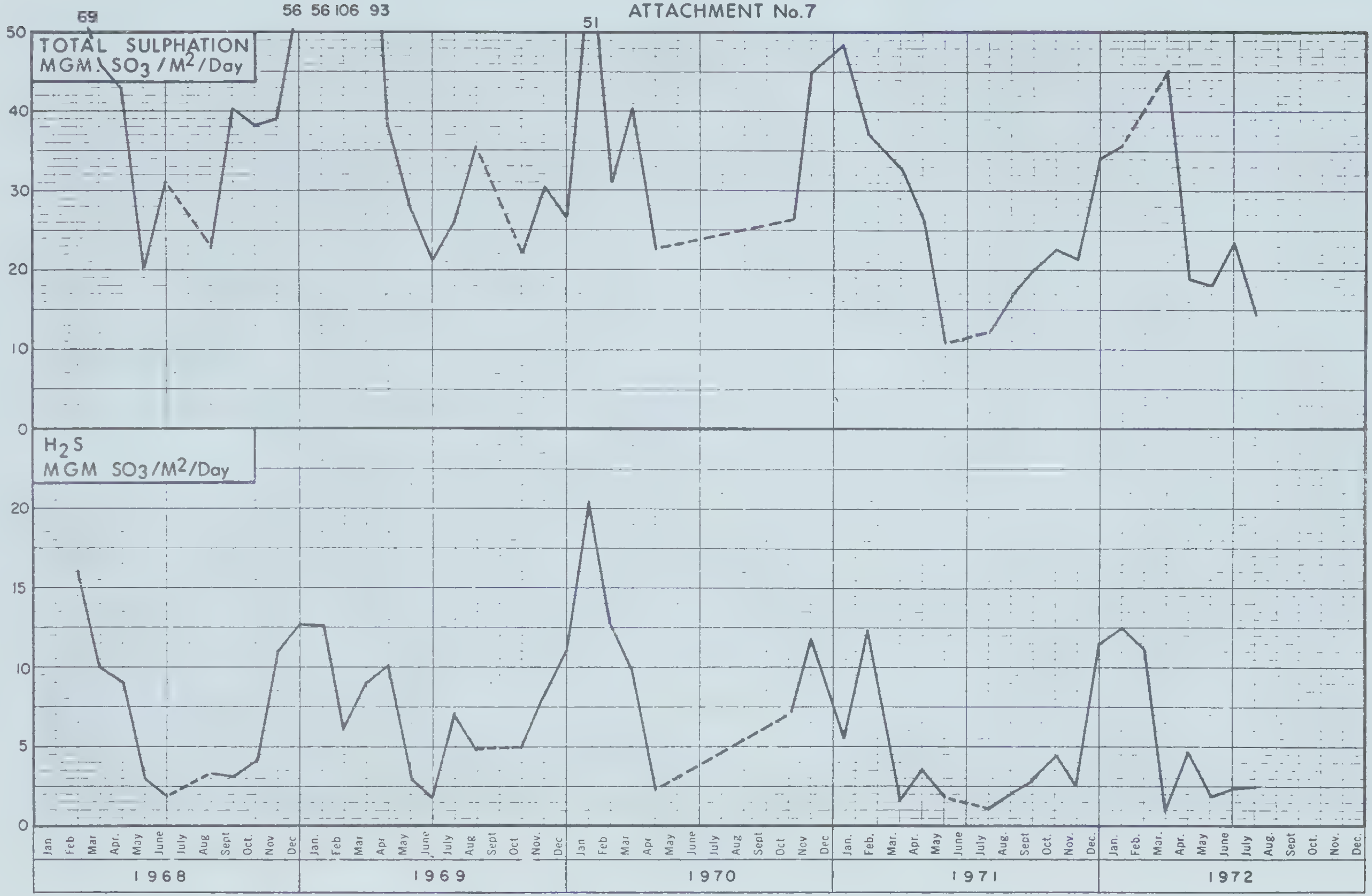
EAST CROSSFIELD PLANT

ATTACHMENT No.7

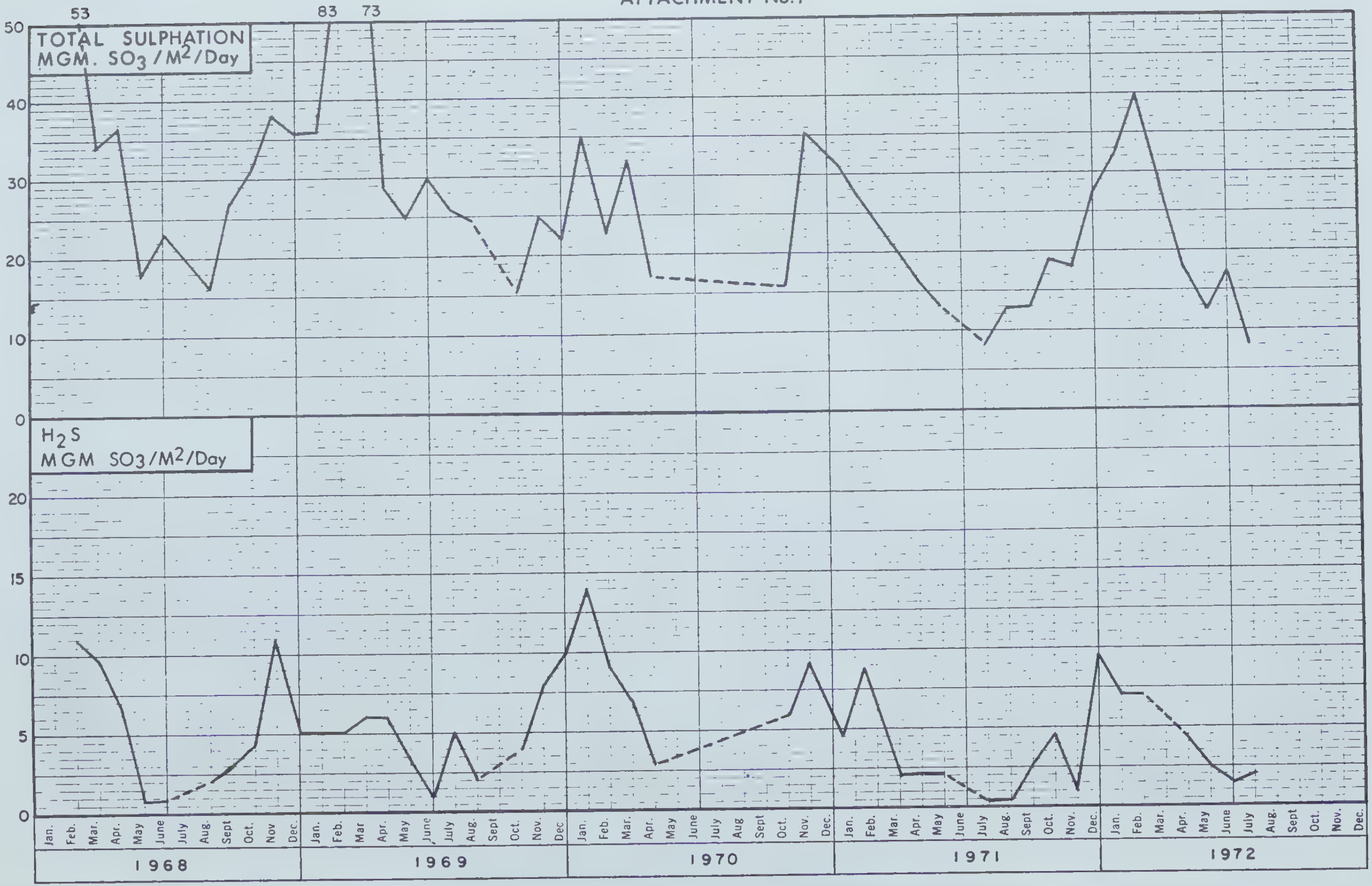


STATION No. 17

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.7



STATION N

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

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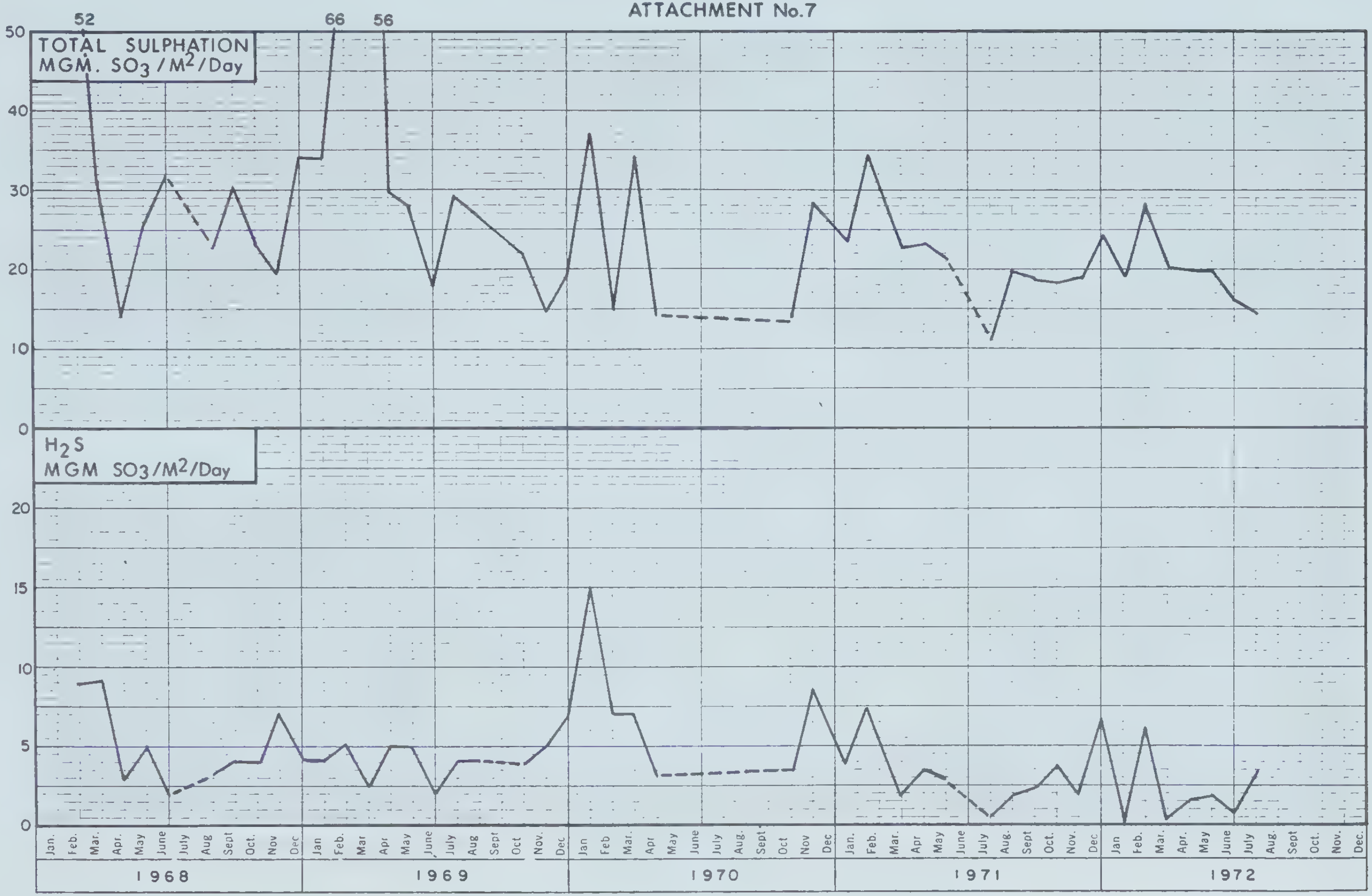

STATION No. 19

Amoco Canada Petroleum Company Ltd.

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

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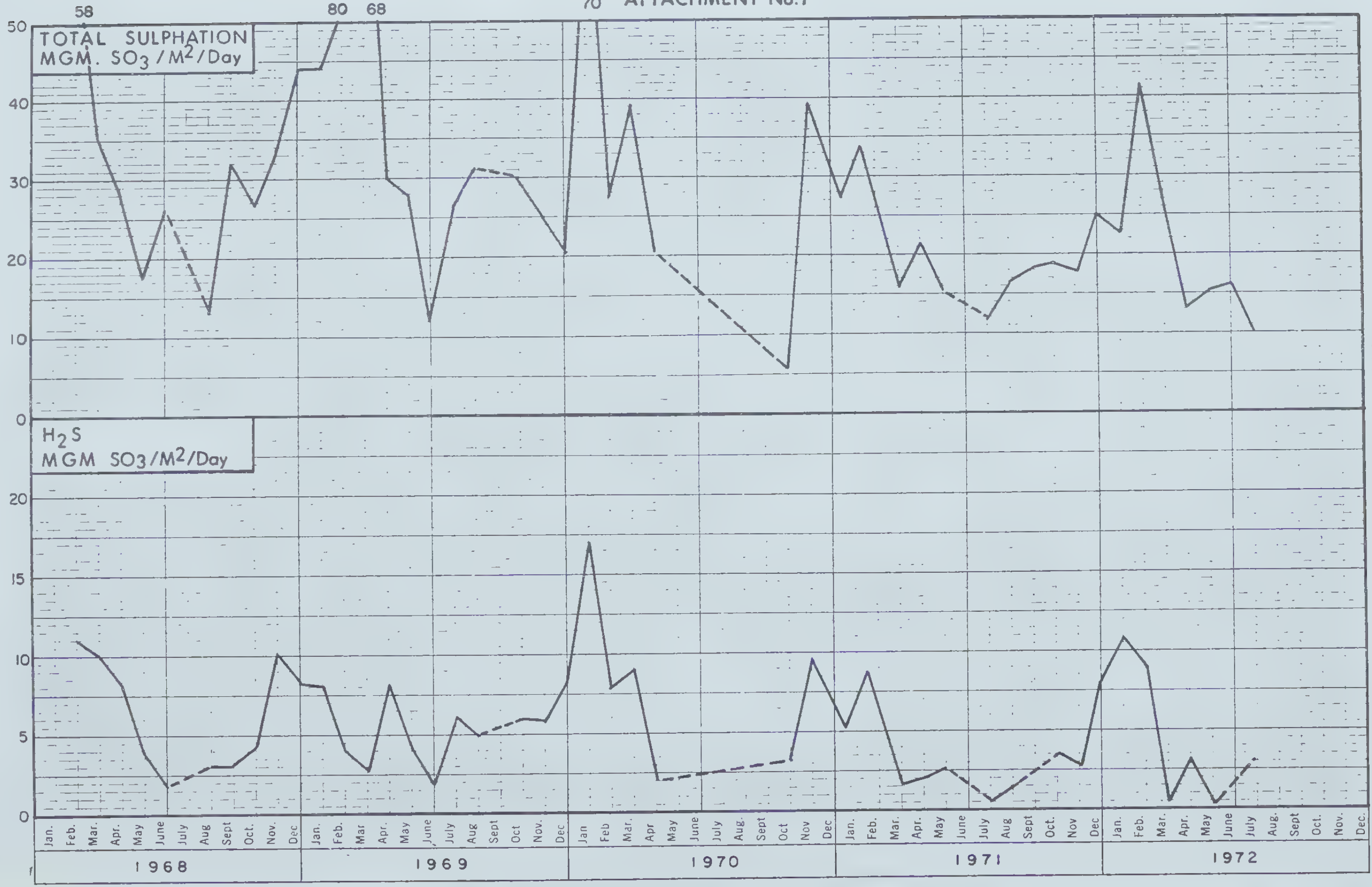
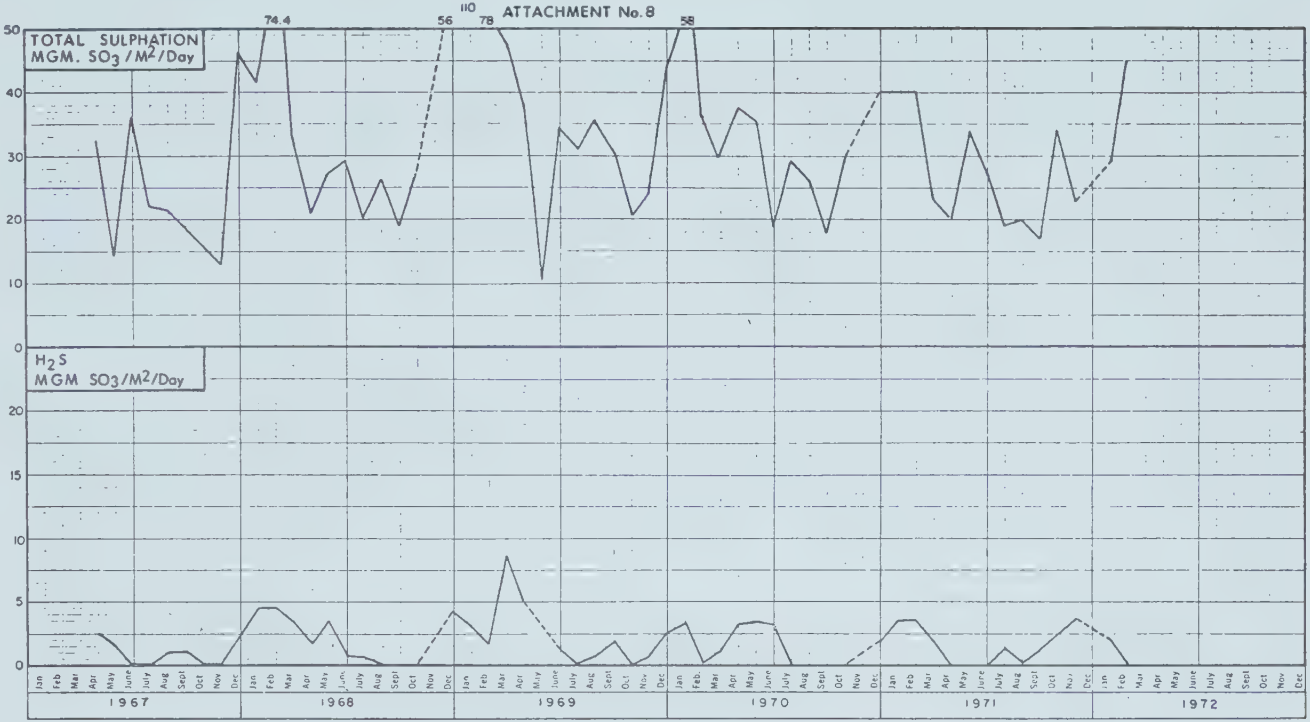


STATION No. 20

Department of Environment

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

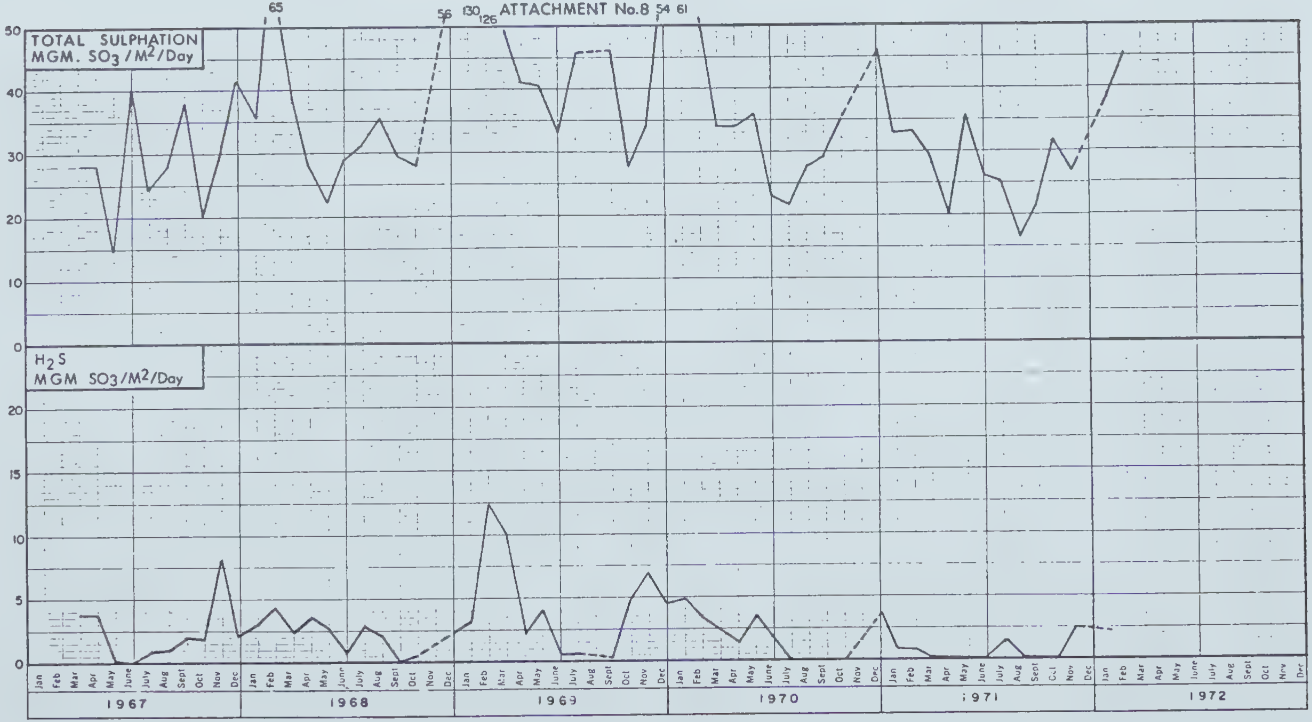
ATTACHMENT No. 8



STATION No. 2

Department of Environment
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

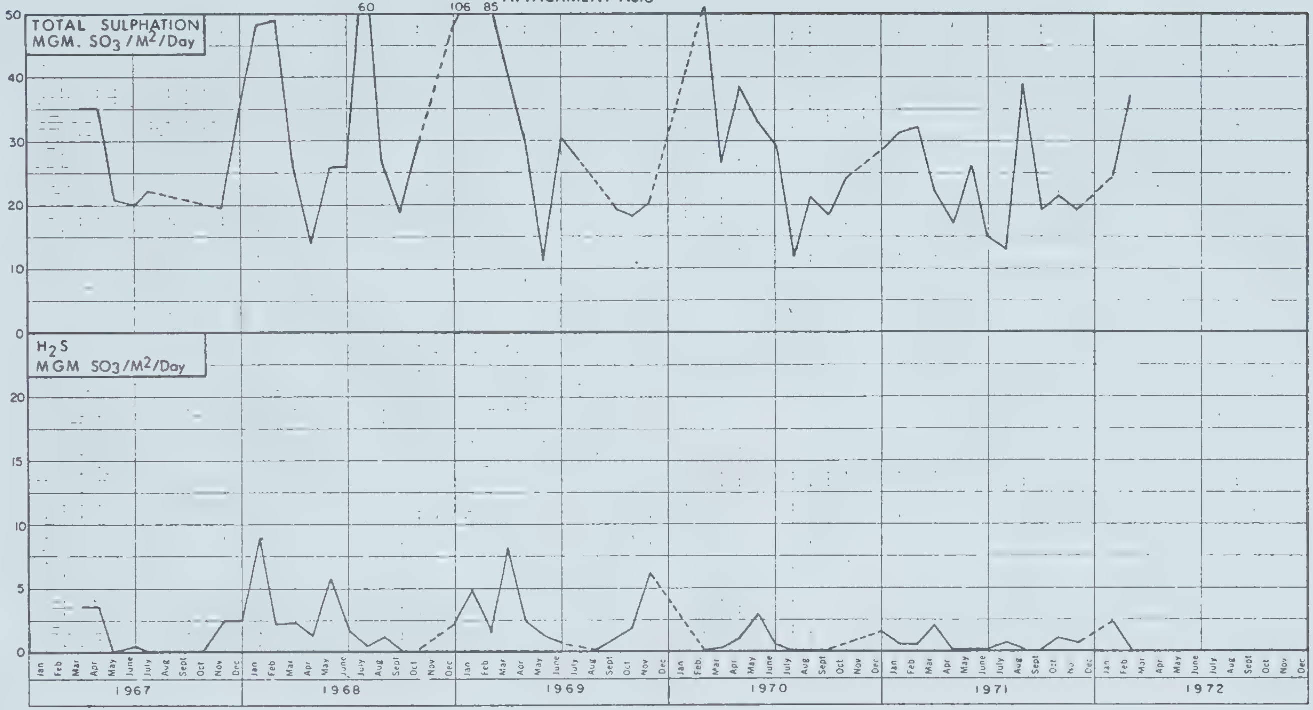
ATTACHMENT No.8



STATION No. 3

Department of Environment
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.8



STATION No. 4

Department of Environment
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

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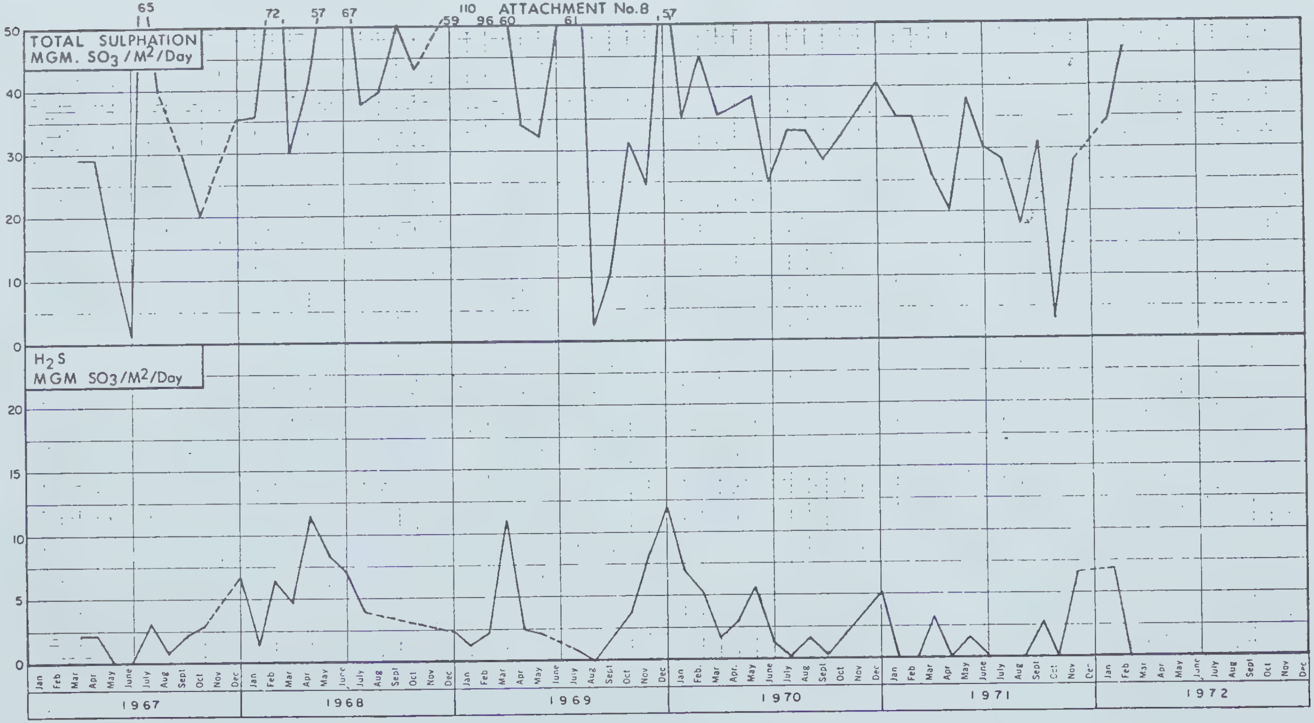
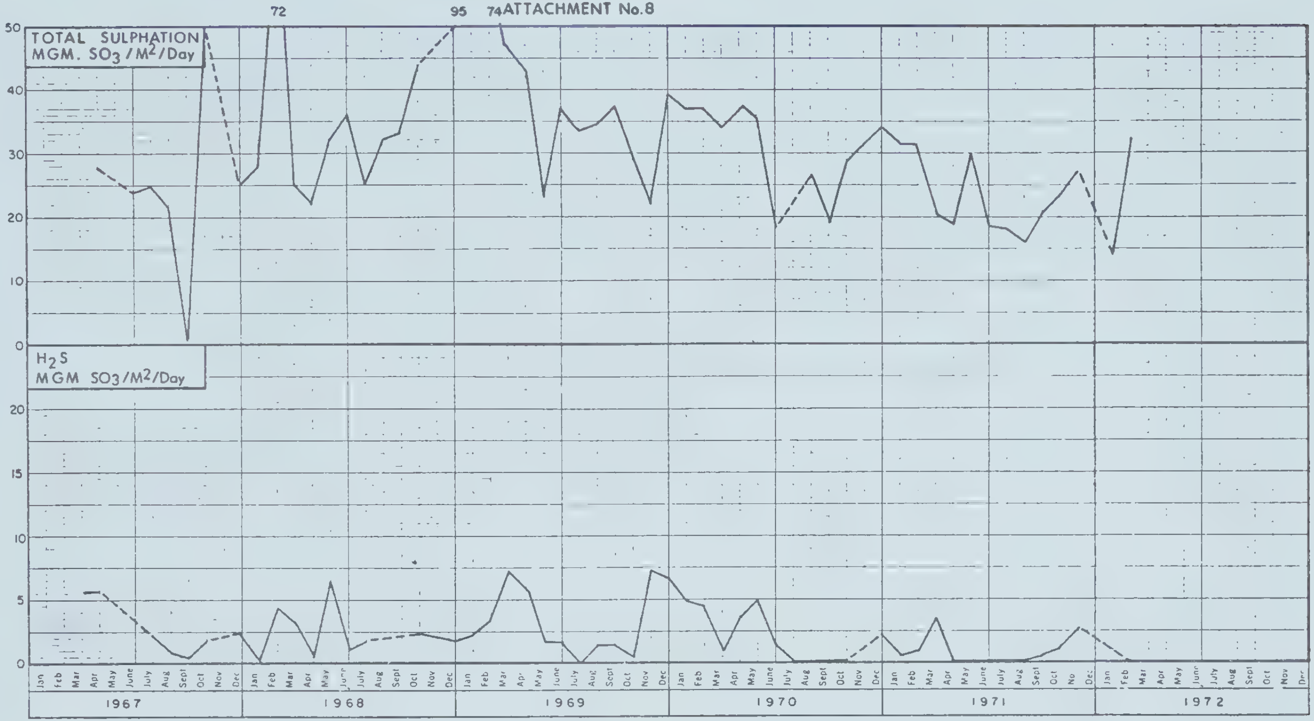


STATION No. 5

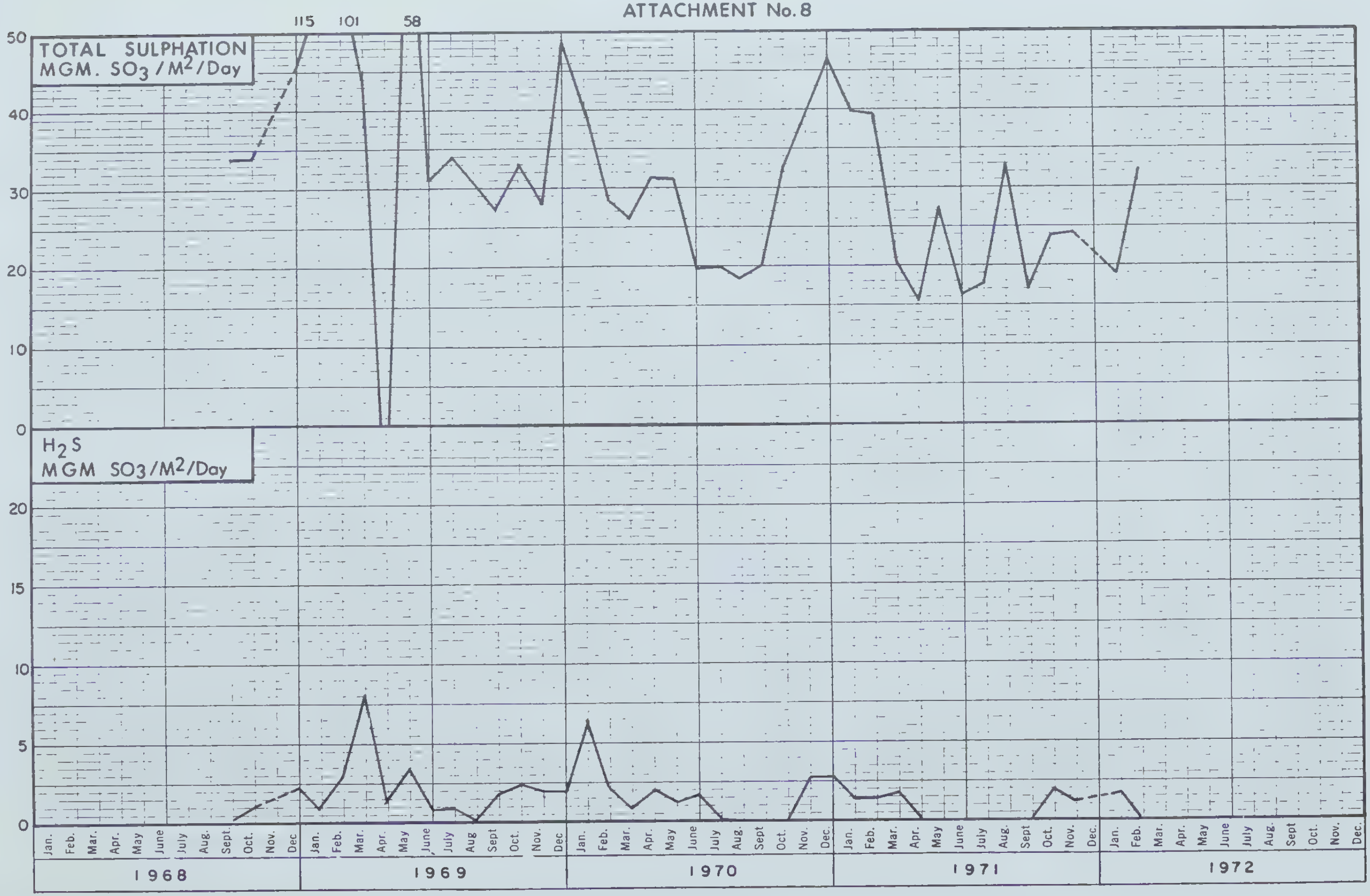
Department of Environment
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.8



STATION No. 6

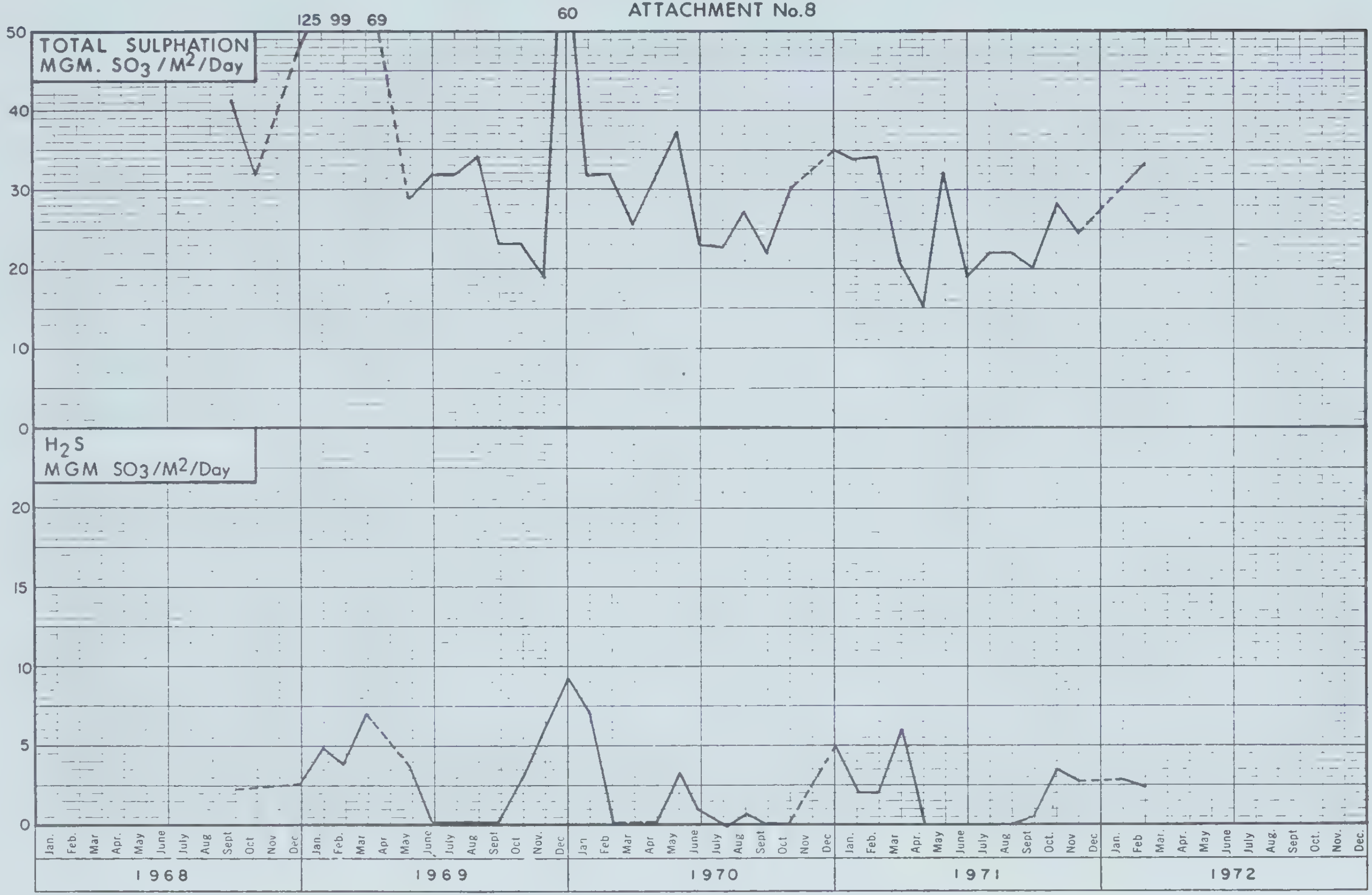
Department of Environment
ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT
ATTACHMENT No. 8



STATION No. 7

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.8

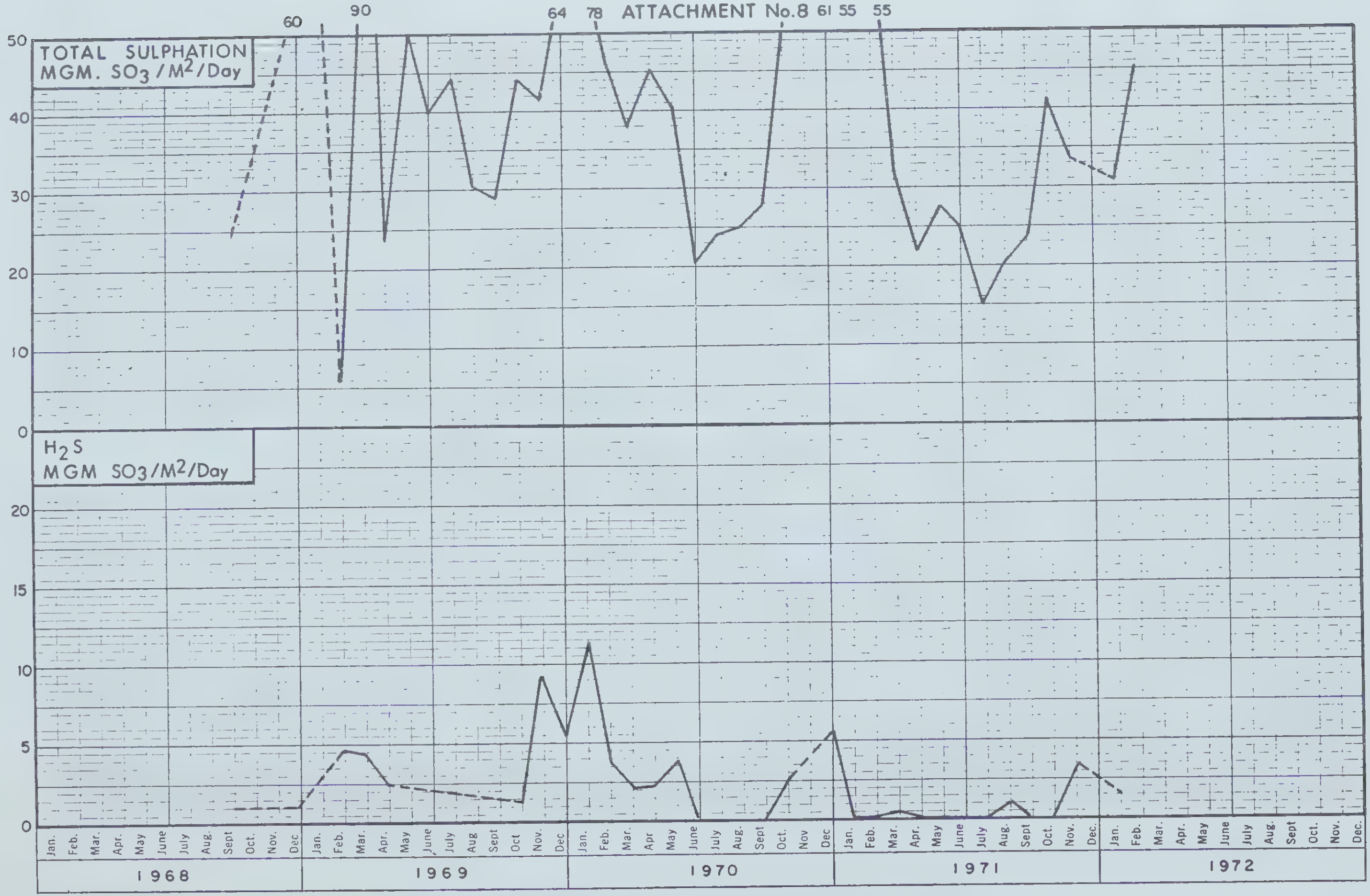


STATION No. 8

Department of Environment

ATMOSPHERIC EXPOSURE CYLINDER RESULTS
EAST CROSSFIELD PLANT

ATTACHMENT No.8



STATION No.9

ATTACHMENT NO. 9

Frequency of Occurrence of Various SO_2 Concentration Levels Monitored at East Crossfield D-1 Plant

(April 1972 to January 1970 inclusive)

Date	0.051-0.10 ppm Level Minutes	0.11-0.20 ppm Level Minutes	0.21-0.30 ppm Level Minutes	0.31-0.50 ppm Level Minutes	0.51-0.70 ppm Level Minutes
April 1972	60	30	0	0	0
March 1972	0	15	0	0	0
February 1972	150	60	0	0	0
January 1972	390	75	0	0	0
December 1971	945	60	0	0	0
November 1971	15	0	0	0	0
October 1971	70	40	0	0	0
September 1971	105	30	0	0	0
August 1971	80	15	0	0	0
July 1971	0	0	0	0	0
June 1971	0	15	0	0	0
May 1971	53	8	0	0	0
April 1971	165	0	0	0	3
March 1971	15	0	0	0	0
February 1971	Equipment Down For Repairs				
January 1971	Equipment Down For Repairs				
December 1970	64	120	0	0	0
November 1971	Equipment Down For Repairs				
October 1970	215	135	0	0	0
September 1970	119	71	0	0	0
August 1970	4	8	8	3	0
July 1970	1	5	0	0	0
June 1970	Report Missing From Files				
May 1970	Report Missing From Files				
April 1970	Report Missing From Files				
March 1970	Equipment Down For Repairs				
February 1970	Equipment Down For Repairs				
January 1970	0	0	0	0	0
Total	2,451	687	8	3	3

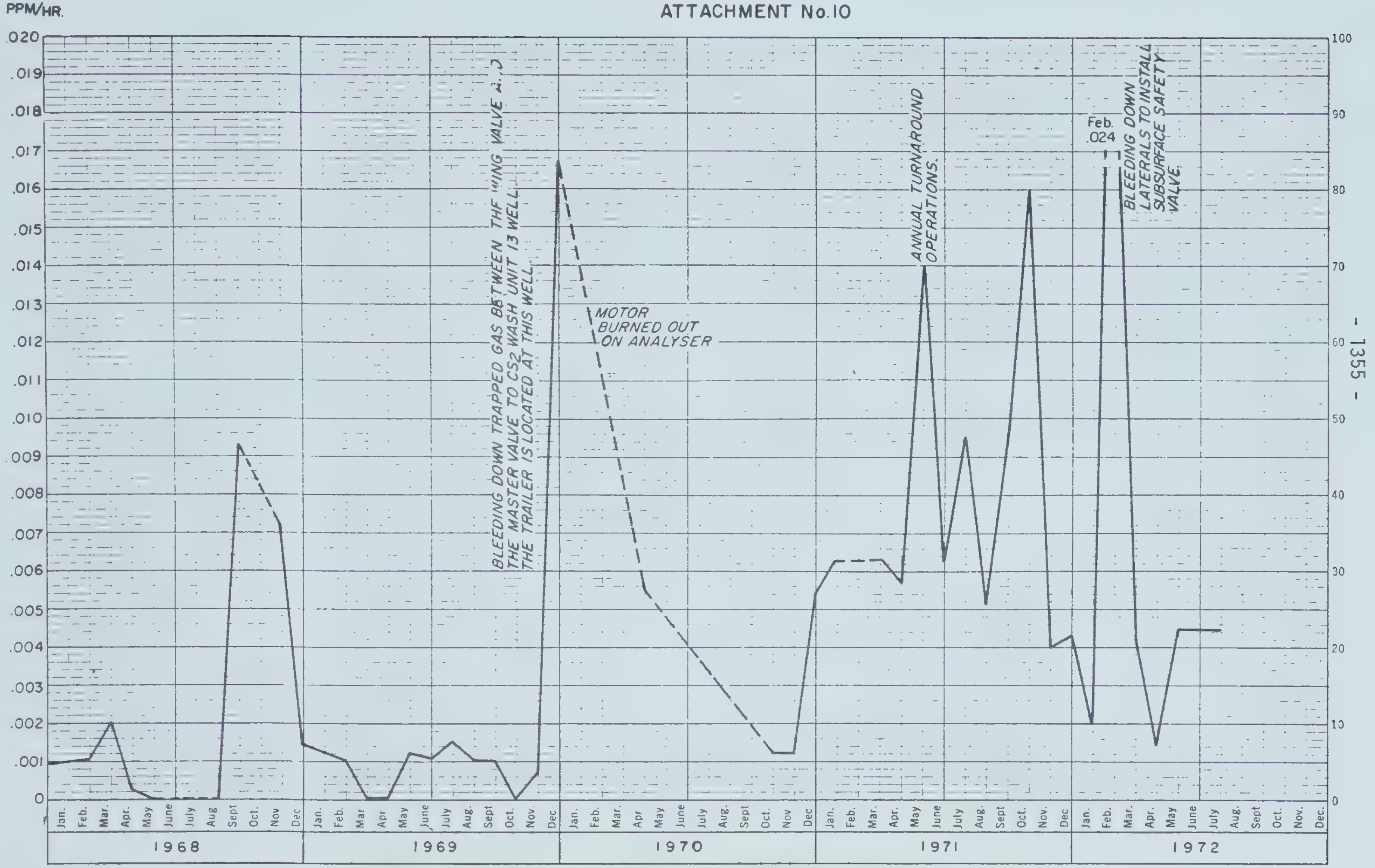
ATTACHMENT NO. 9

Frequency of Occurrence of Various SO_2 Concentration Levels Monitored at East Crossfield D-1 Plant

(December 1969 to May 1968 inclusive)

Date	0.051-0.10 ppm Level Minutes	0.11-0.20 ppm Level Minutes	0.21-0.30 ppm Level Minutes	0.31-0.50 ppm Level Minutes	0.51-0.70 ppm Level Minutes
December 1969	0	45	0	0	30
November 1969	60	0	0	0	0
October 1969	30	0	0	0	0
September 1969	Equipment Down For Repairs				
August 1969	75	30	15	15	0
July 1969	154	54	76	160	0
June 1969	118	361	69	98	12
May 1969	155	640	125	0	0
April 1969	212	990	30	15	0
March 1969	190	180	190	0	0
February 1969	Equipment Down For Repairs				
January 1969	Equipment Down For Repairs				
December 1968	346	80	38	0	0
November 1968	107	798	147	0	0
October 1968	15	384	0	26	0
September 1968	167	49	142	159	0
August 1968	165	77	60	66	0
July 1968	Report Missing From Files				
June 1968	340	423	238	42	0
May 1968	126	53	96	76	0
Total	2,260	4,164	1,226	657	42

PEAK H_2S READING
EAST CROSSFIELD PLANT
ATTACHMENT No.10



ATTACHMENT No. 11

COMPARATIVE TAIL GAS CLEANUP PROCESSES

98% RECOVERY-CAPITAL COST

Contractor	Pritchard	Parsons	IFP
Process	Clean Air	Beavon	Polythylene Glycol
Contractor Specified Overall Recovery	98.2%	98.0%	98.1%
Capital Cost (1)	$ 3,968,300	$ 4,021,600	$ 2,690,000
Annual Operating Cost	$ 511,940	$ 583,290	$ 566,000
Present Worth, Discounted At 10% (2)	$ 6,909,050	$ 7,372,050	$ 6,268,000

(1) Includes Initial Catalyst & Chemical Charges.
(2) Includes Capital & Operating Costs Only Over A 10 Year Life.

COMPARATIVE ANNUAL OPERATING COST

Labor	$ 61,320	$ 61,320	$ 49,000
Power	$ 214,620	$ 153,300	$ 115,000
Steam	$ 21,900	$ 22,340	$ 5,000
Treated Water		$ 23,360	
Water Injection	$ 100,100	$ 6,260	
Fuel Gas		$ 60,270	
Chemicals		$ 142,350	$ 156,000
Maintenance	$ 114,000	$ 114,090	$ 108,000
Plant Overhead			$ 79,000
Taxes			$ 54,000
Total	$ 511,940	$ 583,290	$ 566,000

ATTACHMENT NO. 12

COMPARATIVE TAIL GAS CLEANUP PROCESSES

99% RECOVERY - CAPITAL COSTS

Contractor	Pritchard	Parsons	IFP
Contractor Specified Overall Recovery	99.5%	99.0%	99.0%
Capital Cost (1)	$ 5,795,410	$ 5,080,360	$ 4,120,000
Annual Operating Cost	$ 806,530	$ 743,780	$ 691,000
Present Worth Discounted at 10% (2)	$10,428,200	$ 9,352,800	$ 8,488,000

(1) Includes Initial Catalyst & Chemical Charges.
(2) Includes Capital & Operating Costs Only Over A 10 Year Life.

COMPARATIVE ANNUAL OPERATING COST

Labor	$ 61,320	$ 61,320	$ 49,000
Power	$ 386,320	$ 202,360	$ 126,000
Steam	$ 43,800	$ 28,030	$ 5,000
Treated Water		$ 30,030	
Water Injection	$ 100,100	$ 6,260	
Fuel Gas		$ 79,890	
Chemicals	$ 51,100	$ 193,450	$ 156,000
Maintenance	$ 163,890	$ 142,440	$ 165,000
Overhead			$ 107,000
Taxes			$ 83,000
Total	$ 806,530	$ 743,780	$ 691,000

QUESTIONING BY THE AUTHORITY

DR. W.R. TROST

Are the cost data that you just finished showing us, and for which we do appreciate your co-operation, presently included in the submission that you have here?

MR. A. NEIDERMAYER

Of course they were not in the submission, Dr. Trost; we compiled these for the presentation today at your request.

DR. W.R. TROST

Is there a supplementary submission?

MR. A. NEIDERMAYER

We have not prepared one but we could do so if you wish.

DR. W.R. TROST

Could you send it forward somehow or other because I thought it was interesting and quite relevant to the question. In respect to Dr. Holmes making a supplementary submission is there new material that hasn't been presented before in the material that he might present?

MR. A. NEIDERMAYER

Of course each plant is unique. I don't believe that there would be anything particularly relevant in a re-hash of our review. I think the work done at Okotoks and the work done at our plant are very comparable.

DR. W.R. TROST

Then perhaps we might forego since we have to get home tomorrow. We were interested in the kind of co-operative research program that the plant had developed at Whitecourt and you were, I think, one of the groups participating in it. Do you want to describe for the records here at these hearings, that co-operative research program that has been referred to before today but hasn't really been defined?

MR. A. NEIDERMAYER

The Whitecourt Environmental Study Group was evolved as a result of the number of plants that were in that Whitecourt forest area. There were twelve plants there and eight operating companies; initially there was some suggestion of interference between plants, and of course each owner was interested in starting to take a closer look at the environmental effect, the intrusion that this industry was having on the environment there. It appeared logical that this might be best served by a group effort. In this part of the country we have been proceeding on a separate basis. We did however have Dr. Holmes come up today; that was sponsored by four member companies and I feel that possibly a joint effort in this part of the country may develop as well.

DR. W.R. TROST

Quite a sensible and useful way of looking at it, isn't it?

MR. A. NEIDERMAYER

I think again we have a potential interference problem between plants, and if we look at it jointly I think that we will get a better perspective of the whole problem.

DR. W.B. SMITH

I was very interested in the first few sentences of your presentation with regard to questions I have asked a number of other oil company representatives or industry representatives; that is the public involvement which you obviously have deliberately generated to acquaint people with the kinds of things that are going on at the plant. This apparently has not been universal across the industry from the response that we got, and some people have not had a continuing program. Do you place a considerable amount of stress on this with your supervisory staff in the Crossfield operations -- that this is an important part of your responsibility to keep the public informed and to allay their fears that there may be things going on that they don't know about -- and does it help?

MR. A. NEIDERMAYER

I think the locale will have a bearing on that decision. We operate a plant in Whitecourt and the nearest party is basically the Town of Whitecourt some 30 miles away, so you know our concern there wasn't as it is where we are located right now. The collection system for the 35 wells that we operate encompasses the village of Crossfield, and in addition we have 179 farmers located immediately adjacent to our facilities, so the concern there that we had a potentially hazardous material being conducted through wells and flow lines inti a plant was quite high and occasionally there are problems. We felt from the outset that we had to involve the public in our activities. Before we started up the plant we had a public meeting, as a number of other plant operators have done, and attempted to inform the public of our activities in the area in our plant. Subsequent to that there was an emergency measures organization formulated to, in essence, evacuate the village of Crossfield. We were instrumental in assisting the town in developing that plan. We felt that this was important; that we thought our operations would ever necessitate such a move, but it was something to be prepared for. In addition, we feel that we must keep track of the farmers in the locality; farms are abandoned and people move around and we have to know where these people are. That is why we make an extra effort to go out and visit them annually and know that they are still there and what their telephone numbers are, and of course we have impressed this on all the people in our organization. Quite frankly, I think that as a result of taking the initiative here, we have avoided some of the problems that other operators possibly have had.

DR. S.B. SMITH

It seems to me that this has been highly successful in the populated areas. The Crown land area -- forested areas in all directions around Whitecourt -- are becoming more and more heavily used by hunters and fishermen. The recreational potential of that area is growing almost weekly. You can see a very observable difference year by year and there are good data to back this up. Do you not think that it might be worthwhile to at least periodically involve such organizations as the Whitecourt Road and Gun Club (if there is one) and the Town Council there or the Chamber of Commerce, or something like this, in a similar fashion to periodically expose your operations to them so that they have a better understanding of the problems that we face? If it has been successful in the farm communities, why not in the other communities where there is a growing involvement of use?

MR. A. NEIDERMAYER

I think you related the statistical incidence of something happening to that hunter, that visitor on that road, when he is just coming into your area occasionally, to the situation you have in Crossfield where those people were living there 24 hours in a day. The incidence of disasters or problems associated with our operations were very very low. We had one pipeline break and one heater break in our operation at Crossfield, and these occurred very shortly after startup as a result of some problems in hardware. Since that time we have not had a problem. Nevertheless, those people are there continually so they require that sort of attention. I am not sure how you control the hunter, the visitor or the Sunday driver in a forested area. I might add that our staff is a part of the Whitecourt community. We do have employees who are members of the Fish and Game Association so they are able to pass it on in less formal ways, but I think there is a pretty good knowledge of our operation in the area just as a result of informal conversation.

MR. W.A. FLOOK

You showed a picture of your mobile monitoring trailer and the text of your brief indicates that it is located two and one-half miles to the southeast of your plant. Is this the only one that you have?

MR. A. NEIDERMAYER

Yes.

MR. W.A. FLOOK

How did you arrive at that location? Presumably it is downwind from the prevailing wind.

MR. A. NEIDERMAYER

This was the choice location. We call it a mobile trailer. Basically it stays at that location all the time. We had one occasion to move it west of the plant to spot-check a high point in the ground and to run a survey there for a number of months, but basically we call it mobile but technically it remains at that one location.

MR. W.A. FLOOK

I presume that the distance of two and one-half miles is your calculated point of impingement based on some wind velocity?

MR. A. NEIDERMAYER

I can't really answer that, Mr. Flook. We felt like this was a good location. The Department of Health at that time and now the Department of the Environment agreed that that was a good location and that is where it is. I don't know of any environmental situation that says that is a better place to have it a five miles or one mile.

MR. W.A. FLOOK

It seems to me that to rely on this one point, unless there was some very outstanding reasons why that one point would be appropriate is probably inadequate, a large percentage of the time as a monitor on the effect of the total environment. Would you agree with that?

MR. A. NEIDERMAYER

No, I can't agree with you at all. If I may just backtrack a little bit, we do have 28 cylinders out there measuring H_2S and sulphation as well. They are strategically located all the way around the plant. To me, the best monitor we've got out there is the plant; that small plant, that barley field, whatever is growing around there. I feel that we've got literally hundreds of thousands of monitors, and if we take the time to go and check these at the appropriate times and see that we are not stressing these plants as a result of our emissions, then we are doing an optimum job. Also, I think our association with the people in the community in turn gives us a bit of a monitor. The peopld do talk to us. They know where we are. We do get feedback and, quite frankly, I think that it is a secondary monitor that is probably second only to that small plant that is our there continuously being exposed to whatever emissions comes from our plant. I feel that we are adequately monitoring the environment, somewhat different than you might suggest. To me the sulphation cylinders and the continuous monitoring trailer is a kind of policing effort to ensure that we are not really going wonky.

MR. W.A. FLOOK

That of course is the point. Philosophically I agree with you, although to a lessor extent in the second case then in the first. I think the plants are probably more valid than the people because possibly a very good P.R. program could invluence the feedback you got there; however, that is a philosophical but you still have to meet prescribed government regulations which indicate -- and the word is quite specific -- that ambient air quality standards must remain at a certain numerical value, and to monitor it at one single point which is appropriate only under one set of wind conditions in one direction from the plant seems to me to be inadequate. In fact, for another plant that was using seven trailers I almost got some agreement from the proprietor that that might be inadequate as well.

MR. A. NEIDERMAYER

Again, I have to relate to that plant out there that is really telling us what is going on and if in fact we are not doing any harm, and we see no distinct evidence of any harm at this point, to me the actual concentration is probably irrelevant. You might calculate that it should be this, and you may say that that is the maximum, but we do know that there are meteorological effects that override some of these things on occasion. We do get these heavy concentrations because of a roll-over or something like that, and to me if they occur infrequently enough and we see no harm out there, isn't that what we are really looking for?

MR. W.A. FLOOK

It may be what you are looking for, but I think I've got my andwer from you quite well. Thank you.

MR. A. NEIDERMAYER

I would like to add one comment here. Where there is continuous monitoring relayed and telemetered back into the plant, you are purported to have an ability to respond to high readings; I am quite frankly not convinced at this point that if I get a high reading and I effect a cutback, that I am really going to do any good out there, because I'm not sure that these roll-overs are for short periods of time and that the adverse effect, whatever it might be, has already occurred.

GENERAL DISCUSSION

DR. W.R. TROST

Are there any comments from any person who has not yet made a submission or made any statement.

MR. J. HARPER

I am Mr. Jack Harper of Western Decalta Petroleums. I would like to ask questions which would apply to the application of the arts that we are hearing today. First of all there is an article that I am familiar with from the last hearings by Dr. Klemm where reference was made. I believe it was on page 75. It was a section referring to tail gas cleanup methods. I have heard no comment at this particular series of hearings suggesting potential cleanup in the avenue of disposal into wells. I do have some appreciation for sulphur dioxide problems of injection; we have heard references to the cost to basic industry of some of these new plant additions. We have also heard from expert witnesses regarding directing research to the future in sulphur. Is anyone still present who could make any comment where there is research being done in the form of injection systems?

DR. J.B. HYNE

The possibility of sulphur sour gas processing plant effluent being disposed by re-injection either into specially drilled holes, chosen formations or into depleted formations even with the potentiality of improved secondary recovery has been examined over the last ten years. As is probably well known, disposal of liquid effluents into deep holes is a practice that occurs in Alberta right now. The major problems that one faces in attempting to dispose of sour gas processing plants' tail gas are, first of all, the enormous volumes. As was indicated this morning it is not simply the three percent residue of the hydrogen sulphide that you have to get rid of; that three percent is massively diluted with nitrogen, water, carbon dioxide and various other material so that you are looking at a disposal problem that involves volumes that are essentially in the same order of magnitude as the sales gases that you are producing. As far as reinjection itself is concerned, there are technical problems that are associated with the compressor equipment necessary for this. The gases themselves are corrosive and the pressures involved, considering the composition of these gas mixes, the possibility of switching back and forth from the gas phase to the liquid phase and getting condensation; this presents serious compressor design problems. The final point -- that is poorly understood -- is the possible interaction of these re-injected gases with the materials of the formation; one possibility is the actual Claus reaction taking place down on the catalytic surface of the formation rocks, and of course plugging off the formation rather quickly. These are a few comments, but in essence I would say that this matter has been looked at and to some extent is still being examined; these give you some idea of the problems that are involved. It is not an easy solution.

MR. J. HARPER

I wonder if I could redirect the question. The statement, I gather, relates more principally to the tail gas cleanup aspect of it. We are aware of some selective processes that... and one of the commodities no doubt is the high volume of CO_2 which may be present in some gas streams. I would just like to ask if there is any research now going on at the level of, say, the injection of liquefied hydrogen sulphide, or hydrogen sulphide as a gas to a reservoir or selective process may just render that product only available?

DR. J.B. HYNE

I will answer one-half of that question, and then I would defer to someone else who is more knowledgeable about injection practices in Alberta.

On the matter of selective dissolution of the hydrogen sulphide from the gas stream, the questioner is quite right, there are commercially available techniques such as Selexsall, Purasall, which are essentially solvent techniques for selectively removing carbon dioxide or hydrogen sulphide from the gas stream, separating it and then presumably disposing of it separately. The major problem here is these are all solution processes and if you are passing the main volume of the gas to this system to separate it H_2S to CO_2 you have enormous pumping problems because the throughput of the selective solvent is clearly enormous in order to handle it. Let us, however, assume that you can separate the hydrogen sulphide. Is it being re-injected anywhere in Alberta? Not to my knowledge, but perhaps someone else in the audience can give a more definitive answer to that part of the question?

MR. C. CHALMERS

As you mentioned yesterday, we have two stacks at Petrogas. Each of these stacks is emitting to the atmosphere 110 million cubic feet per day of vapors. These vapors consist of 27 percent water, 72.5 percent nitrogen and 0.5 percent SO_2. This is the tremendous volume that Dr. Hyne was talking about. Just to try to control that water alone, which is a highly corrosive liquid.

MR. J. HARPER

That answers the questions that I wished to present at this time.

DR. W.R. TROST

Any further discussions or questions from the floor? I would like to thank all of you for participating in these hearings and for bringing this information and evidence before us. That you very much.

ADJOURNMENT